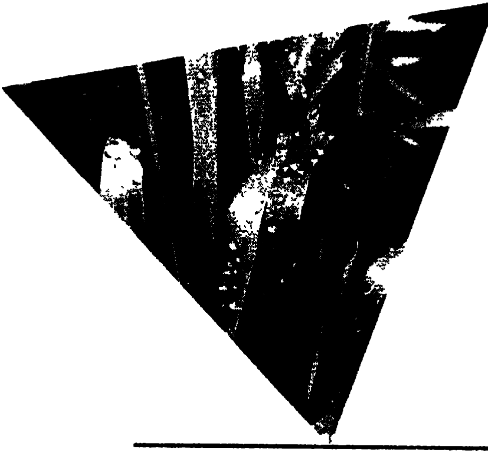
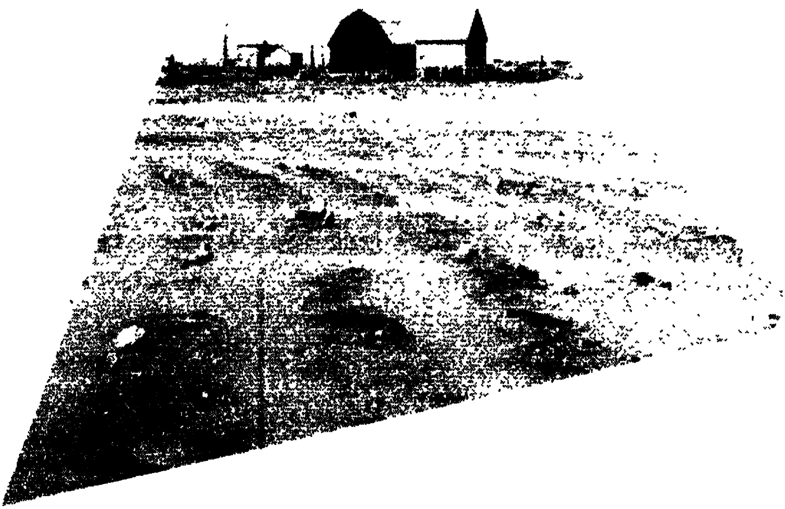
Soil

AND

SOIL

USE and IMPROVEMENT





SOIL

USE and IMPROVEMENT

J. H. STALLINGS

Research Specialist in the United States Department of Agriculture

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Preface

Erosion is the greatest destroyer of our soil, although it need not be. For many years erosion nullified the beneficial effects that had been the result of our improved knowledge of farming and kept our national acre yields from increasing. Until recently the damage from erosion had offset the total gains made by the adoption of advanced soil and crop management practices, of improved crop varieties, of the increased use of fertilizer and lime, and of better methods for controlling insect pests and plant diseases. In fact, all these improvements were needed just to keep our national acre yields from declining. *Soil: Use and Improvement* explains how wind and water erode the soil, how these damages can be prevented, how our soil can be cropped to full capacity, and how crop yields can be increased—all at the same time.

Soil: Use and Improvement is divided into three parts. Part I, historical in nature, presents a brief survey of the effects of soil erosion on ancient civilizations, as well as on early settlements in this country. Part II is concerned with the fundamental factors that should be considered when dealing with the problems of soil erosion. It explains the erosion of soil by wind and water, the formation and maintenance of soil crumbs (soil tilth), the importance of plant cover in building and holding the soil, and the intricate relationship existing between soil, plants, and animals. Part III studies the remedial measures for controlling erosion and for improving our soil while, at the same time, cropping it to the fullest extent. It discusses control measures for erosion both by wind and water, maintenance of good soil tilth, and the most effective management of our grazing and

woodland. Part III also presents all the elements needed in planning a sound soil and water conservation program and explains how to use them in developing such a plan.

The author trusts that *Soil: Use and Improvement* will be of value to farmers, gardeners, agricultural students, and others who are in one way or another intimately connected with the soil.

J. H. Stallings

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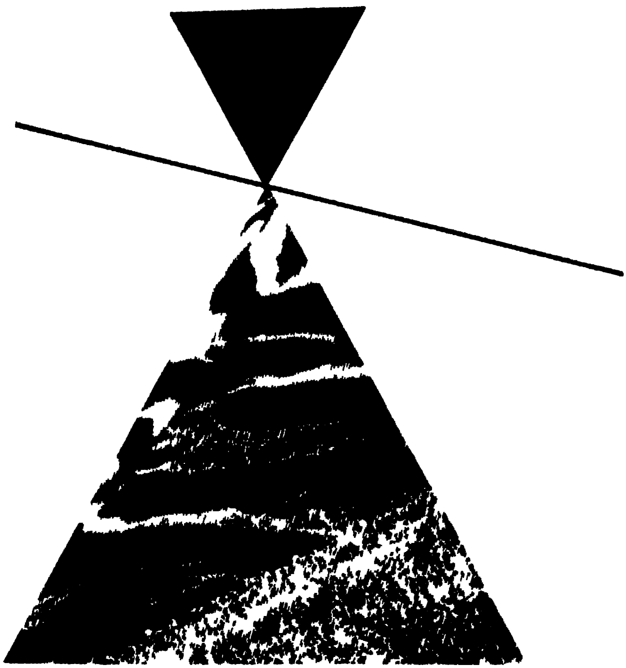
Part I

HISTORICAL ASPECTS OF SOIL CONSERVATION



1

Man's Struggle with Soil Erosion

MAN'S struggle with soil erosion[1] is as old as agriculture itself. Records of his efforts to adjust himself to the land are written on landscapes around the world. Ruined land and starving people show us he failed to care properly for nature's great natural resource—"the topsoil." If we wish to avoid these mistakes we must study the records and know the causes for his failure. Our standard of living depends on food, which comes from the soil. To date erosion is ahead in the struggle—we must find out why.

Nowhere is there anything to indicate he knew the nature of the forces with which he was dealing. Some knew that when the grasses and trees were removed wind and water destroyed the land. They thought the plants slowed the flow of water and kept gullies from forming. Some thought plant roots prevented erosion by binding the soil so that wind and water could not carry it away. Man learned early that erosion became almost uncontrollable as soon as plant cover was removed by cultivation or overgrazing.

Early civilizations let nature's forces destroy their lands. They overgrazed their grasslands and cut the trees from the hills. More land was planted to cultivate crops; timber was needed to build cities; food was needed for growing populations: man was no longer a nomad. Science and art were being developed, and he was be-

[1] The removal of soil by the action of wind and water.

coming educated. But he didn't understand natural laws governing wind and water—laws that would have helped him understand the balance of nature's forces.

Let us see how man's lack of knowledge of nature's laws destroyed the topsoil and caused the downfall of vast empires. We shall now study the history of these early civilizations and learn why many of the countries, where agriculture had its beginning, are wastelands today.

SOIL EROSION IN THE OLD WORLD

Insofar as can be determined, Civilization arose in the Near East. The cultures that developed moved eastward to China, westward through Europe, and across the Atlantic Ocean to the Americas. Some of these civilizations were superior in many respects to some of our modern cultures. Why did they disappear?

Tillage of the soil had its beginning at least 7,000 years ago. It developed in two great centers: in Mesopotamia, along the valleys of the Tigris and Euphrates rivers, and in the Nile River valley. On these alluvial (flood) plains, in arid or dry climates, tillers of the soil began to grow crops by irrigation. For the first time, it was possible for some of the people to do things other than to produce food. Those who tilled the land could now produce in quantities greater than their own needs. This gave rise to what we call civilization.

Mesopotamia is thought to be the place of the Garden of Eden, the Tower of Babel, and the confusion of tongues. Its glories and tragedies are widely known. It was a land of dense populations and great cities, but all that remains today are scattered villages and ruins of great cities.

We need to know why this occurred. Some may say it was because this nation grew up and lived under the threat of raids and invasions by the tribes from the grasslands and deserts. Records show it was due to filling of their irrigation canals with sand from cutover and overgrazed land.

Mesopotamia destroyed the plant cover on land draining into the Tigris and Euphrates rivers and failed to compensate for it. To build the cities, trees were cut off the hills; to furnish meat, milk, and wool for large numbers of people living in cities required large herds and flocks. Thus the grasslands surrounding the cities were overgrazed and the protecting cover was destroyed.

With this plant cover gone, wind and water loosened the soil to wash into the rivers and streams. Irrigation waters were made muddy by soil washed from hills—cutover woodland and overgrazed rolling hills. This sediment caused the fall of the empire.

The velocity of the water slowed down upon entering the irrigation canals and deposited silt, which filled them. Much time and labor were required to remove the silt to keep the canals open, so that life-giving waters could be supplied to farm lands and cities on the plain. As populations grew, canals were extended until they formed a great system. As the canals grew, so did the task of keeping them clear of sediment

Repeated conflicts—both revolts within and onslaughts by invaders—interrupted the task of maintaining the canals. Finally, the combined task of restoring the canals and repelling the invaders became too great, so without irrigation water, agriculture failed. Without agriculture to provide food and fiber, the villages and cities failed, too, and a great empire disappeared. Without water there could be no food; without food, fiber, and water, people in great cities could not survive.

Kish was the first capital after the Great Flood swept over Mesopotamia in prehistoric times. It was built above brown soil deposits, laid down by the flood, which mark a break in periods of culture. Ruins of these periods have been examined and recorded, giving us a fairly accurate record of the part played by erosion in the destruction of this land.

The history of Mesopotamia is the story of a nation destroyed by accelerated or man-made erosion. We shall now compare this with the second center of civilization where there was only natural erosion.

This other great cradle of modern civilization is in the valley of the Nile. Here the mysterious Sphinx ponders the problem of the ages. It looks out over the narrow green valley of the Nile cutting across a brown, sunbaked desert. Here, as in Mesopotamia, farmers grew surplus food. This released their fellows for other work.

From this beginning arose the civilization of the Nile Valley. Muddy waters wetted the lands along the Nile, but they were flood waters from the river. These waters contained only silt and clay or the smallest soil particles. The sediment was rich in plant food. The silt-laden river waters spread over the plain depositing thin layers of silt, raising the plain higher and higher and enriching the land.

Figure 1-1. Excavated ruins of Kish, the first capital of Mesopotamia following the Great Flood. These ruins were completely covered with shifting sands and silt deposits. (Soil Conservation Service Photo)

We now have two areas for comparison. In Mesopotamia the soil cover was removed, and man-made erosion destroyed a great civilization. Let us remember Mesopotamia as a land of mountains, rolling hills, and valleys. In the Nile Valley we have a low plain with only natural erosion. Natural erosion did not destroy the good topsoil on the cultivated land. The silt was brought to the plain by rivers.

Let us follow the route of Moses to find what happened there. Let us see if the same destructive forces, that operated in Mesopotamia, eroded the land there. This route led from the fertile flood-irrigated Nile Valley into mountainous lands, where forests and fields were watered by rain. When the slopes were cleared for cultivation, or overgrazed, water eroded the soil and carved gullies. Today most of these slopes are barren wastelands.

Sinai, where the Israelites wandered with their herds for forty years, is a picture of desolation. The soil has been eroded into enormous gullies.

Because Ezion Gerber, Solomon's seaport on the Gulf of Aqaba, had copper smelters 2,800 years ago, it was the ancient Pittsburgh of the Red Sea. This port is now being dug from under several feet of erosion deposits.

Petra, the capital of Nabatean civilization, flourished at the same time as the Golden Age of China—from 200 B.C. to A.D. 200. It is in ruin.

The Jordan River is now a muddy stream. Soils from more than half the upland area of the Promised Land have been washed off the slopes to bedrock.

Erosion has also taken a heavy toll in the denuded highlands of Judea. Records of abandonment of village sites in Wade Musrara during the past 1,500 years show decline of the land.

The rate of abandonment is related to the altitude and the progress of erosion. In the plain, four villages were abandoned, in the foothills, sixty-five, and in the mountains, 124. These hills are dotted with only a few of their former villages—places where terraces had been kept in repair for more than 2,000 years.

Jerash, a village of 3,000, was once a center of some 250,000 people. The country about it is now sparsely settled with semi-nomads. In Biblical times, this region was famous for its oaks, wheat fields, and well nourished herds. This area supplied grain to Rome and supported thriving communities. When discovered, the ruins of this once powerful city of Greek and Roman culture were buried to a depth of 14 feet by soil washed from the hills.

Figure 1-2. The soil on the slopes at the left was washed off to bedrock. The slopes on the right still retain enough soil to produce light-yielding barley crops. View near Jerusalem. (Soil Conservation Service Photo)

Soil in this area eroded in spite of rock-walled terraces. The ruined terraces are proof of man's fight against erosion even at this early date. Ancient farmers tried to save soil from washing after there was no longer any soil to save. In North Syria—in the limestone country between Hama, Aleppo, and Antioch—an area of over a million acres has lost from three to six feet of soil by erosion. A hundred cities and villages have been abandoned as a result.

The Phoenicians were the first tillers of the soil who came to grips with water erosion on sloping land. Some 5,000 years ago, Phoenician tribes swept out of the desert and occupied the eastern shore of the Mediterranean. In time, they cleared the slopes to cultivate the land near the harbor towns of Tyre and Sidon. Severe erosion followed as a result of hard rains. Ruins of this area show how the Phoenician farmers tried to save their land by constructing walls across the slopes. However, the walls failed, topsoil slipped downhill, and erosion again destroyed a civilization.

The record of the once fertile soil of the Roman Empire in North Africa is no less disheartening. Over a large portion of this area, the

Figure 1-3. The remains of what once was a populous city in Syria during Roman times. A few of the stone buildings in the middle distance are still inhabited; but most of them are in ruin. This ancient city was never covered by erosion debris, but the topsoil was washed away and only a few hundred inhabitants remain where there were once thousands. (Soil Conservation Service Photo)

Figure 1-4. The magnificence and former glory of Rome. The city of Timgad, North Africa, is in deserted ruins, surrounded by a desolate countryside. (Soil Conservation Service Photo)

soil washed off to bedrock; the hills are carved by deep gullies. At Djemila, an ancient city was uncovered. Except for about three feet of a single column, this city was completely covered by silt and sand washed from the surrounding hills. Under this soil material, diggers uncovered great temples, two great forums, splendid Christian churches, and huge warehouses for wheat and olive oil. The surrounding slopes, now barren and gullied, had once been covered with olive groves.

South of Guicul is Thamugadi—now called Timgad—another Roman city founded by Trajan in the first century A.D. It was laid out in symmetrical pattern and adorned with magnificent buildings. It had a forum decorated by statuary and carved porticos; a public library; a theater to seat some 2,500 people; and seventeen baths with marble flush-toilets. After invading nomads completed the destruction of the city and the dispersal of its population in the seventh century, this center of culture was lost to knowledge for 1,200 years. It was buried by the dust of wind erosion. Only a portion of Hadrian's arch and three columns remained, like tombstones, above the sand to indicate a great city was once here. Water erosion cut a gully down into the land and exposed a canal that supplied water

to the city of Timgad from a spring three miles away. Ruins of large olive presses were dug up, although today there is not an olive tree to be seen in any direction.

Indications of what happened to the fertile soils of North Africa are found on the hillsides between Constantine and Timgad. Botanists tell us that these hills were once covered with savannah vegetation of scattered trees and grasses. Plants conserved a layer of soil on these hills for unknown ages, but with the coming of a grazing culture, brought in by invading nomads of Arabia, erosion set in. Accelerated runoff cut gullies into the upper edge of the topsoil. The soil moved downhill like a great rug being pulled off the hills, and was dumped lower down.

We have just reviewed some ancient history: history not of wars and war-like destruction but of the destruction of the topsoil—the food-producing, the life-giving soil of some ancient lands. Let us remember this lesson well. In all but one country we find the cause and results the same. The ancient tillers of the soil failed because they removed the natural cover. Man lacked knowledge so did not see the real cause of erosion.

Not until the trees, grasses, and litter were gone from the slopes did man try to check erosion. Erosion was destroying the land, bringing thirst and starvation to his people. This record in man's history tells a tragic story. It is a record of his failure to care for the greatest natural resource—the topsoil—God has given him. This ancient history points out a lesson: Man's greed to build great empires led him to ignore nature's laws governing soil and water. This oversight could have but one result—destruction of his soil. Civilizations vanished, buried under the silt, dust, and rubble of the soil eroded from their hills.

EARLY AMERICAN EXPERIENCE

Next, we shall study about the early agriculture in America. We shall compare ancient agriculture with problems faced by early American pioneers as they concern soil erosion.

As soon as early settlers of this country cleared away the forests and plant cover for cultivation they ran head on into soil erosion. As long as land was plentiful, a farmer could clear new land as fast as the "old" "wore out." Eventually, there was no new land to clear,

and it was necessary for farmers to live with the land they had.

This brought soil erosion problems into the open. The settlers became frightened, as well they might. They did not know how water eroded their soil. They recommended measures, similar to those that failed ancient farmers, aimed at controlling surface runoff. They recommended measures to control something they didn't understand. Some even concluded that soil just wore out and plants failed to grow.

Some farm leaders recommended deep plowing, contour tillage, hillside ditches, and terracing. These were aimed at controlling surface runoff and were practiced by some farmers. Broadbase terraces with a slope for drainage and grassed outlets were used on a Virginia farm in 1838.

Sorsby of Hinds County, Mississippi, wrote a prize essay on "Horizontal Plowing and Hillside Ditching" in 1857. He cited work of this type done on the plantation of his father-in-law. Sorsby knew that the up-and-down-hill method of culture, then in general use, was destroying the land.

Despite the teachings and work of men like Sorsby and his followers, there were some who realized these practices were not enough. Some were afraid of them. This view was stated by Massey of North Carolina in 1907 He found terraces and ridges worse than no treatment during hard rains. During floods, water overtopped ridges and terraces and broke them, which resulted in more erosion than as if they hadn't been there. Several farmers reported similar views, and some were bitterly disappointed with deep plowing on slopes of 10 to 15 per cent.

These fears were set forth in the leading agricultural literature of the day. The *Agricultural Volume*, Report of U.S. Commissioner of Patents, 1852, shows their uneasiness.

This report shows that soils of the South were destroyed by the system of agriculture used on the plantations. This destruction was the work of intelligent men—worthy citizens and true lovers of the country. The plantation owners and landlords of the South were honorable, highminded men and were always ready to sacrifice self-interest for public good. If these men were here today and could see the destruction of their soil and their states, they would be the first to brand themselves as "land killers."

SEARCH FOR NEW METHODS

Some lost faith in the prevailing methods of managing cultivated land, so they started in search of new and better methods. Some observed that the rate of erosion was reduced by using crop rotation, or by decreasing the length of time soil was exposed to rains.

In 1876, Pendleton of Georgia found cultivation of rolling land difficult. Water washed off topsoil and cut gullies, especially where corn and cotton were grown. He noticed crop rotations protected soil better than continuous cropping, allowing soil to stand up against the forces of erosion. He knew land deteriorated when planted to cultivated crops; improved when abandoned and allowed to grow up to weeds. The weeds and grass protected the soil and preserved organic matter, but cultivated crops didn't.

In 1906, Spillman recommended the use of terraces as a substitute for shallow plowing. He also noticed land eroded badly when planted to cotton, but that it didn't when planted to grass, or when kept in clover or other cover crops.

An important discovery was made about twelve years ago. We found that erosion by water started when falling raindrops struck bare ground. They blast soil particles loose. Before this discovery, we thought surface runoff alone eroded our soil, that is, that shallow sheets of water flowing over the ground tore the soil loose. This revelation showed us surface flow was only one factor—a junior partner in eroding our soil.

At the same time, we found that plant cover—so abundant nearly everywhere—is the countermeasure to raindrop splash. We found that plant cover protects soil from beating raindrops as well as from wind.

Discovery of the raindrop's part in the erosion process explained man's failure to save his soil. We hadn't suspected that the raindrop did any more than supply water to make the runoff.

DEVELOPMENT OF U.S. DEPARTMENT OF AGRICULTURE PROGRAM

By the turn of the century, the U.S. Department of Agriculture began to develop a soil erosion program for the nation. Like all such previous programs, it was based on surface runoff. *Farmers' Bulletin*

20, 1894, discussed eroded soils and how to reclaim them. The U.S. Department of Agriculture *Year Book* of 1903 discussed the relation of soil porosity and granulation to the washing of soils. It advised use of deeper plowing and terraces to prevent it, but no clearly defined national policy of soil erosion control was outlined until 1907.

RESEARCH ON SOIL

In 1877, Wollny of Germany found that plant cover protected soil from the impact of raindrops. He noticed that the loose, granular structure of unprotected soils broke down, and became hard and compacted during rains. At the same time, the porosity or open space was decreased, which resulted from muddy water seeping into the large pores. Fine soil particles filled the pores. He concluded that plant cover protected soil from the impact of falling raindrops. It caught raindrops and kept them from pounding the soil.

Wollny also found that as the slope became steeper erosion increased more rapidly than runoff. He proved grass cover reduced both runoff and erosion. He thought that plant roots bound the soil and the tops reduced the rate of runoff. He found that grass was more effective in the second year because it made better cover than in the first

The Soil Conservation Service got results similar to Wollny's. Lowdermilk of California and Hendrickson of Georgia showed that pore space in the upper inch of soil choked with clay and silt when muddy water was poured on it. Neal of New Jersey and Free of New York proved that the impact of raindrops destroyed the open structure of the top inch of soil This formed a dense, nearly impervious surface that reduced infiltration.

IMPORTANCE OF PLANT COVER IN EROSION CONTROL

We knew for many years soil protected with plant cover doesn't erode. We thought plant roots bound the soil and the tops slowed surface runoff. We didn't know that plant cover protected the soil by catching raindrops.

Soil Conservation Service workers found straw used as mulch controlled erosion. This was true whether the straw was laid on the

ground or supported slightly above. When straw supported slightly above ground protected soil, they knew surface flow didn't erode the soil; something else did. They noticed litter under trees checked erosion, too. These workers found that plant cover kept soil open at the surface, so it could absorb rainwater rapidly. They also discovered that runoff and erosion increased when plant cover was removed.

Other Soil Conservation Service workers saw that soil detachment—tearing soil particles loose—and erosion went hand-in-hand. They found plant cover effective in reducing splash erosion. Those workers noticed that damage to topsoil increased as the height of plants increased and decreased as the ground became more completely covered. The better the soil was covered the less the soil loss. Oat straw mulch was more effective per unit weight than sweet clover mulch, because oat straw was compact and covered the ground well. Sweet clover was open and didn't cover as well.

Soil Conservation Service workers in New York found straw mulch reduced splash loss 98 per cent. It reduced loss from running water by 66⅔ per cent. They used soil in pans supported above the ground, and exposed to rain. Soil, in pans not mulched, formed crusts that reduced the rate in which soil absorbed water.

Another Soil Conservation Service worker found a connection between the force applied by raindrops and the amount of water erosion. The amount of force applied by raindrops was determined by size of drops, speeds at which they fell, and how much it rained. These same factors determined how much soil was lost.

With an artificial rain maker, water drops were applied to soil in trays. The drop size ranged from one to five millimeters in diameter. Seventy per cent less water was absorbed by soil sprayed with five-millimeter drops than with one-millimeter drops. Erosion losses were 1,200 per cent greater with the five- than with the one-millimeter drops.

SHIFTING EMPHASIS

The soil erosion movement is now passing into a new stage. The main emphasis in the past was on surface runoff, because it was believed that that alone caused soil erosion. Discovery that raindrop splash is the main factor in water erosion shifts this emphasis. It marks the end of one era and ushers in another. *For the first time,*

we know how to control soil erosion. Since the raindrop's part in soil erosion escaped man's detection during the first 7,000 years of civilization, it explains why there is so little or no erosion on land with ample plant cover. Indeed, it explains many things that puzzled agricultural leaders and farmers throughout this long and troublesome period.

We have known for a long time that plant cover was the best way to control wind erosion; now we know it is the best way to control water erosion. Better still, we know how plant cover controls both wind and water erosion and how to put this knowledge to work.

The Babylonian, Phoenician, and other ancient cultures didn't know about raindrop splash, or that they sowed seeds of their own destruction when they destroyed the trees and grass. They didn't know plant cover was needed to catch falling raindrops. Had they been aware of this, their history may have been far different, because there wouldn't be the extensive areas of eroded and abandoned land there are in the world today.

Egyptian civilization started in the Nile Valley about the same time Babylonian civilization started in the valleys of the Tigris and Euphrates. There was no man-made erosion in Egypt, but there was in Babylon. The Egyptians are with us today; the Babylonians disappeared long ago. At least ten other civilizations that followed the Babylonians on the same land also disappeared.

The discovery that falling raindrops beating on bare soil is the main cause of soil erosion by water has opened up a new field. For the first time, we know why bare cultivated fields erode severely during hard rains. We also know why portions of the same or adjoining fields with good cover experience little or no damage during the same rain.

Foliage, leaves and litter, and dead plant parts intercept or catch falling raindrops. They break the force of the drops and ease them to the ground as clear water. The raindrop does not make direct contact with the ground surface, so is robbed of its energy. The soil surface isn't disturbed, and the clear water enters the ground freely. Failure of the ancient farmers of the Near East to make this discovery set civilization back several thousand years. This same discovery, had it been made earlier, and applied sooner, would have saved much of the best soil in America.

Now that we have discovered the real cause of erosion, let us

profit by the lessons taught by the past. Let us use this knowledge to preserve and improve the soil of our farms so that America will be strong, well fed, and her people prosperous and happy.

EXERCISES

1. Select a site covered with plant growth or a bare spot, preferably on a slight slope. If the site is covered with plants, take a hoe and scrape away the plants from a portion of it. Now play water from a garden hose on both the sodded and bare plots to simulate rainfall of medium to heavy intensity. If the entire site is bare, place a 1-inch-deep layer of straw, leaves, or other trash on a portion of it and leave the rest bare. Play water on the site as described above. On one plot there will be little or no erosion. On the other erosion will be severe. Explain this phenomenon. How does it relate to man's struggle with erosion?

2. Select a bare spot on either a slight or steep slope. On a portion build a ridge to simulate a terrace. Place a 1-inch-deep layer of straw or other trash over the other portion. If it is not convenient to use a garden hose, as described above, wait for a rain of medium-to-heavy intensity. Which treatment is the more effective in controlling erosion? How is this related to erosion problems on the farm?

3. Select a spot covered with sod or crop residues or other trash, preferably on a slope. Take a spade and turn the plant cover on one portion under. Either play water on each plot, as described in No. 1 above, or wait for a rain of medium-to-heavy intensity. Which portion of the site was damaged by erosion? Does this prove anything about the effectiveness of plowing as an erosion control measure?

QUESTIONS

1. What knowledge did the farmers of ancient lands lack that would have enabled them to win their fight against erosion?
2. How did the type of agriculture practiced by the farmers of the early civilizations cause their lands to erode?
3. How long ago and in what country did tillage of the soil begin? Locate this country on the map and describe what the people and the country were like at this time.
4. Why did the irrigation system fail in Mesopotamia?
5. Why did agriculture in the Nile Valley prosper while in Mesopotamia it failed? Locate this valley on the map and describe the area.
6. Trace the route followed by Moses on the map. How did the topography of this region cause erosion to be more destructive than in the Nile Valley?
7. What was the land of the Israelites like at the time of Moses? What is it like today? What caused such severe erosion in this area?

8. Who were the first farmers to make any attempt to save their land by use of soil conservation methods? How do we know they did this?
9. What was the real cause of the destruction of Babylon?
10. Locate Timgad. Describe what it was like at the time of the Romans. What type of erosion destroyed this great civilization?
11. What is meant by savannah vegetation? Soil detachment? Surface runoff?
12. What lessons can be learned from this ancient history of agriculture?
13. What errors did the early soil conservationists of America make? What caused some of the southern planters to doubt the wisdom of using some of the soil-conserving practices advocated at this time?
14. What discovery was made that changed our whole idea of how best to control water erosion?
15. Give several good reasons why soil erosion is a national problem.
16. What discoveries were made by Wollny of Germany and the Soil Conservation Service research men of America that aided in finding the real cause of water erosion?

2

Soil Erosion in the United States

In 1934, a quick check was made of soil erosion in the United States. The results surprised us all—even those who knew most about soil erosion. Erosion was more serious than any of us thought. More than half of our land was damaged, some of it was abandoned.

This check showed that 282 million acres of land was seriously eroded. This land once grew crops like cotton and corn, but it was so badly damaged we couldn't grow crops on it any more. We had abandoned some of it as worthless. Another 775 million acres were badly damaged. They were in cultivation but in need of repair, and of protection from further damage to keep them from being destroyed or abandoned.

In 1948, the Soil Conservation Service made a study of erosion in four states—Arkansas, Louisiana, Oklahoma, and Texas. This study showed over 14 million acres of land was seriously damaged, with much of it abandoned. We could no longer grow crops on it. Another 259 million acres were damaged in varying degrees.

This study showed damage to the land, but not the abandoned homes, and hopes that went with them. It didn't show increased flood damage caused by the damaged land or filled and abandoned reservoirs that had furnished water and power. It didn't show a number of other damages caused by erosion on this land.

We can see how this affects our ability to feed ourselves. Our land is being destroyed, abandoned for no further use. At the same

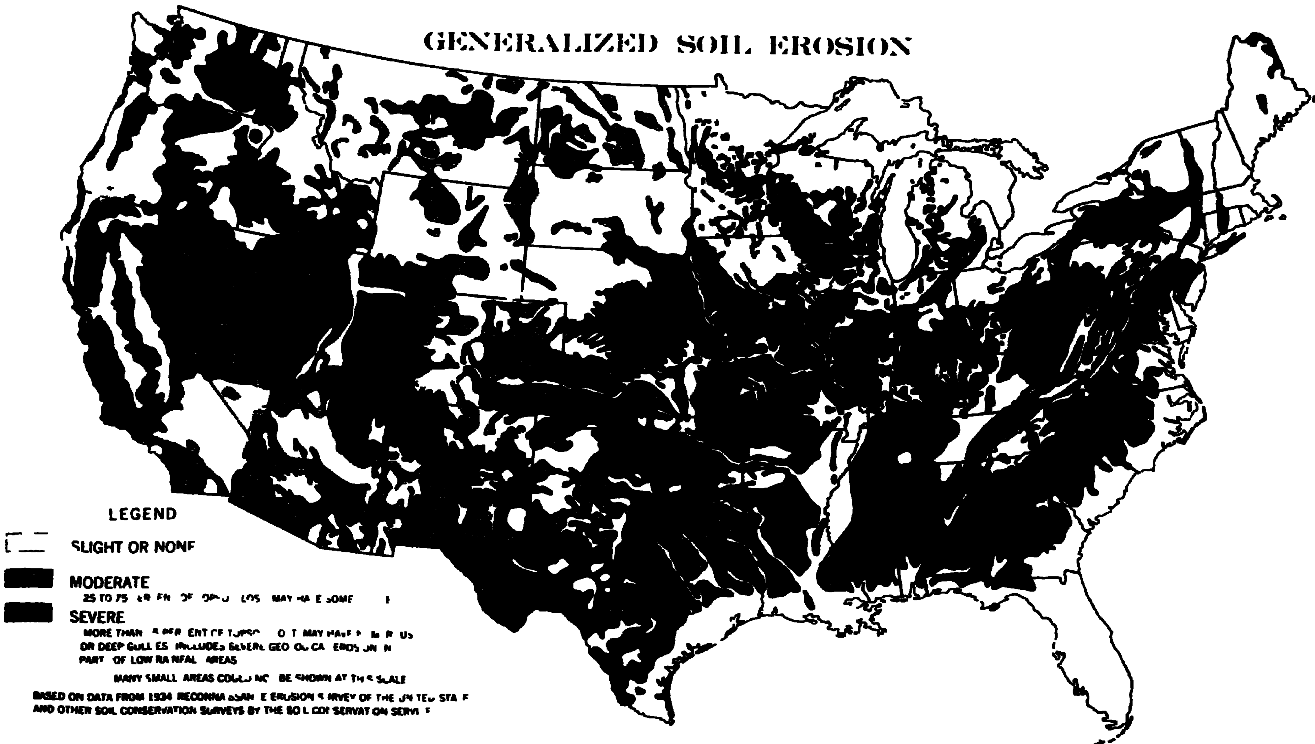


Figure 2-1. Soil erosion conditions in the United States, shown by a survey made in 1934. (Soil Conservation Service Photo)

time our population is increasing at the rate of 2.8 millions a year. We can see our food need growing; our ability to produce it is going down.

That's what happened to Mesopotamia, the Romans, the Phoenicians, and others. The signs are plain enough for all of us to see. We all have an interest here, as well as a responsibility. It is for you and me to do our part to swing this thing around.

For the first time in history we know how to control soil erosion, and even how to grow cultivated crops and build our soil up at the same time in order that it will produce more for increasing population. We know how to reclaim some of the abandoned land—we all have to work to make it possible.

MAN RESPONSIBLE FOR EROSION

We have made extensive studies in this country to determine what causes erosion and we found that some erosion occurs under natural conditions, without our aid. This we call natural erosion (of little importance to us, though). Natural erosion occurs in areas undisturbed by man, such as those burned over by lightning or overgrazed by wild animals. Stream and river banks erode under some conditions without our aid.

Soil material removed by natural erosion often is made up of organic matter and silt and clay particles. This material is rich in plant food, is light, and floats in running water where it is carried long distances by rivers. It is deposited by floodwaters on broad, flat plains along river beds. Flood waters almost stop flowing when they spread over flat plains, and such particles carried in the water settle out. This may make flood plain soil rich.

We have made a number of studies to see how much of our erosion is natural and how much is man-made. We found little evidence of the former. Nearly all of our erosion is man-made, because everywhere our forefathers settled this kind followed. Everywhere our early settlers cultivated or overgrazed the land, erosion set in. Erosion increased on our farms and in our streams and rivers, too, and was a problem wherever plant cover was destroyed.

We have made many erosion measurements throughout the country that show the rate is related to use and condition of the land. Our findings varied from location to location and from time to time, but they consistently showed that erosion increased when we used the land.

Man-made erosion produces large amounts of sand, silt, and gravel. These are carried from fields to stream systems and are dumped at lower levels. This sediment harms the drainage, reduces fertility on sloping fields and on bottomlands, and fills stream channels and reservoirs. This damages water supply, irrigation, drainage, navigation, and flood control works. Sediment dumped on roads and highways increases repair costs, and that dumped in irrigation canals increases cost of crop production.

Erosion damages all our soil, by removing plant food and making soil poorer. Erosion damages our forests, grasslands, and cultivated lands. The greatest damage is in our croplands, because they have less plant cover than the woodlands and grasslands and less protection against water and wind.

The widespread erosion sediment is the most important problem we have in our streams. It increases cost of operating canals and reservoirs, affects our health and damages ten classes of public and private enterprises and the general welfare: (1) public health, (2) water supply, (3) fisheries, (4) valley agriculture, (5) drainage, (6) irrigation, (7) flood control, (8) river commerce, (9) recreation, and (10) electricity production.

Erosion sediment often fills our streams, thereby stopping water that flows off the land. This stops natural drainage, and water spreads over cultivated land to create swamps in the fields and pastures. Channels filled with silt do not move water freely, so water not moving through channels piles up and spreads over surrounding lowlands. Pools of water, standing after each overflow, make good places for mosquito breeding. Hence, silt produced by erosion turns productive land into swamp. This condition exists on much of our bottomlands.

LOSSES ON CROPLAND

Soil erosion losses are important locally on our forests and range areas, but losses on our land used for cultivated crop production affect us all. They are of national importance. Erosion is damaging most of our 450 million acres of cultivated land.

Losses on forest and range lands affect a few people; those on cultivated land affect us all. Because these damages reduce our food supply, we have less to eat, and it costs us more to produce the same amount of food.

The tragedy of this is we can't recover these losses—they are gone forever. Our land is worth that much less for raising our food. We use

more fertilizer, better crop varieties, and more power to produce an equal amount of food. Our costs go up; our food production goes down.

Thirty-five million acres of our cultivated land can't grow food for us any longer. We have abandoned it as worthless. We have put another 100 million acres of cultivated land in trees and grass, because it was damaged so it was too costly for us to cultivate. We are "wearing out" a half-million acres more each year.

We think our soil losses by erosion are four billion tons a year. From one-fourth to one-third of this chokes our stream channels and fills our lakes. Choked stream channels cause floods, because the water, unable to drain off fast enough during hard rains, spreads out over bottomlands. Silt and clay are floated into our lakes, causing the flow of water to stop or slow when it enters our lakes. The silt and clay spreads out, giving us less storage space and less water for use.

WIND EROSION LOSSES

Our study showed over 100 million acres are damaged by wind erosion, and we think that 10 million of these are *badly* damaged. Farmers have abandoned much of this land.

We found wind, like water, removed plant food first, because our organic matter and silt and clay go first. This portion of our soil holds food for our plants. The light-weight material is blown away, and heavy sand is left in our fields after dust storms. Sand won't grow good crops.

Most of our wind erosion damage is in arid or dry regions but is the worst in the "dust bowl." The dust bowl covers parts of Colorado, Kansas, New Mexico, Oklahoma, and Texas. In areas where we have lots of rain, wind damages our soils some, although the damaged areas are small.

DAMAGES ON GRAZING LAND

Our study showed wind and water damages large areas of our grazing land. Destruction of our soil reduces the amount and quality of grass we can grow. Poor cover giving less protection to the soil increases runoff and erosion damages on our grazing land. As runoff increases, the amount of water entering the ground decreases and less water enters or infiltrates the soil.

Low infiltration reduces the amount of water to grow our grass, which means less feed for our stock and less meat and milk for us. Increase in erosion means more sediment for our streams and ponds, more water for floods, less water for our grass, and less feed and water for our stock.

Erosion on our grazing land is due to drought—not enough rain—and overgrazing. Drought and overgrazing reduce plant cover and expose our soil to the action of water and wind.

We have droughts three years out of ten over large areas of our rangelands. Droughts hurt or kill grass on our ranges, so in order to save our grass, fewer stock should be grazed during droughts.

FLOOD DAMAGE

Heavy runoff from our fields cause floods with the most damage being done to the cultivated land. Flood damages are increased through erosion wastes.

Floods are very destructive to our farm land every year- the damage is caused by both flood water and sediment. Flood waters cut gullies in our fields, erode our hill lands and dump large amounts

Figure 2-3. Furnish Reservoir on the Umatilla River, about five miles upstream from Nolin, Oregon. Reservoir was put into use in 1909. By 1925 it was so filled with erosion silt that it was no longer useful. (Soil Conservation Service Photo)

of soil material on our bottomlands and in our rivers and ponds. Their activities result in such other misfortunes as lowered crop yields on our uplands and bottomlands.

EROSION KILLS FISH

Early settlers of this country found our rivers and lakes filled with fish, the water clear, lots of food and nesting places for fish and little or no silt. Now one finds muddy water in all our streams and lakes in cultivated areas. Our streams carry only fish (like catfish) that live in muddy water. Muddy water won't grow food for clear-water fish, so they are unable to exist in such surroundings. (It destroyed their nesting places, too.)

Clear-water fish feed on small animals, which feed on small plants growing in the water. These plants need sunlight to grow, but silt makes the water muddy enough to shut out sunlight. The light can't get through to the plants, so the plants die. For lack of food the fish die, too.

It is easy to see how muddy water controls fish life. You can do it next time you go on a camping trip, or to a large uncultivated area.

Water in the streams will be clear and will contain lots of clear-water fish, but no catfish. You can see small plants down in the water, because they are green. But you can't see green plants in muddy streams—they aren't there.

By filling our reservoirs with mud, silt that kills fish in our streams affects our city water supply, too. This sediment hurts us in two ways. Loss of soil from our fields reduces the amount of food we can raise, and soil dumped in our reservoirs reduces the amount of water we can store. Erosion of our soils causes both damages.

We examined thirty reservoirs to see where the silt came from and found that most of it was blasted from our fields by falling raindrops. A small amount came from gully banks and channels. Sediment is filling our reservoirs and reducing the amount of water they can store. The amount we have to use is reduced.

Exercises

1. Select a field with a fairly long slope. Examine the depth of the topsoil (dark-colored layer) at three locations: near the top, about mid-way, and near the bottom. Use a spade. Now, compare the height and vigor of the plants growing at each of the three locations. Plant growth probably is poorest at the top. It probably is best at the bottom. See what relation there is between depth of topsoil and plant growth.

2. Find a clear-water pond or stream. Look carefully and see what you find in the way of green plants under the water. Now see what you find in the way of plant growth in a muddy-water pond or stream. Try to explain the differences you find.

3. Find a place in the field where the soil is actively eroding (a gully is best). Follow the gully to its outlet and beyond. Try to find what became of the soil that washed out of the gully.

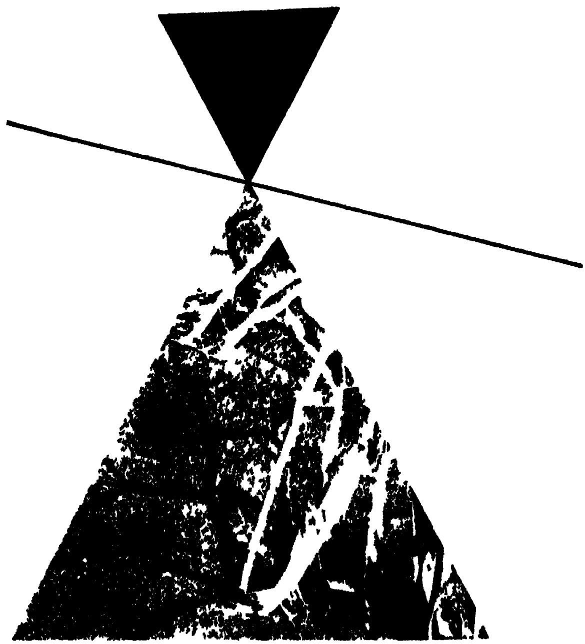
Questions

1. What is the erosion condition of the land in the United States?
2. Does damage to the land tell the whole story about erosion? Explain.
3. How does erosion affect our food supply? What is happening to our population? Why does this make it so important that we control soil erosion?
4. What is the cause of our soil erosion? What proof do we have of this?
5. Name as many ways as you can that soil erosion harms us.
6. How does soil erosion affect land drainage?
7. Why are soil losses by erosion so important?

8. How does soil erosion increase cost of producing food?
9. In what part of the country is soil erosion most serious? Explain why this is so.
10. How does wind damage our soil? Where does wind erosion occur? Why is this?
11. What part of our soil is first to erode? Explain.
12. What part of the soil holds our plant food?
13. How does erosion affect fish? Why are there no clear-water fish in muddy streams?
14. Where does the mud come from that is filling our reservoirs? How does it get to the reservoirs?

Part II

FUNDAMENTAL CONSIDERATIONS IN SOIL CONSERVATION



3

How Water Erodes Soil

FOR 7,000 years, we thought that only flowing water eroded our soil. We believed water running over our fields did the damage. We imagined water tore soil particles loose as it ran over the ground; we never suspected that water eroded soil any other way. It never occurred to us we might be wrong on how water eroded our soil, because we never took time to see what falling raindrops were doing. We kept thinking of surface runoff, so we built terraces or walls around our hills. We thought these walls would keep water from eroding our soil, and that raindrops only supplied water for surface runoff.

When we thought of the raindrop, we thought of its patter on the roof. We thought of being lulled to sleep. We thought of its refreshing grass on the lawn or crops in the field—it is especially so after several days of dry weather. We did notice how water splashes when raindrops fall on pavement or hard ground, and also the geyser-like eruptions caused by raindrops falling on shallow sheets of water.

You may have tasted sand in your spinach and on your strawberries. Then, you may have noticed how dirt splashes on the sides of the house and on basement windows, where the ground around the house is bare. You probably have seen muddy water in field ditches after rains. You may have realized that raindrops splashed the sand on the spinach and strawberries, and dirt on the house and basement windows. But, did you know that raindrops splashed the soil that made the water muddy in the ditches, too?

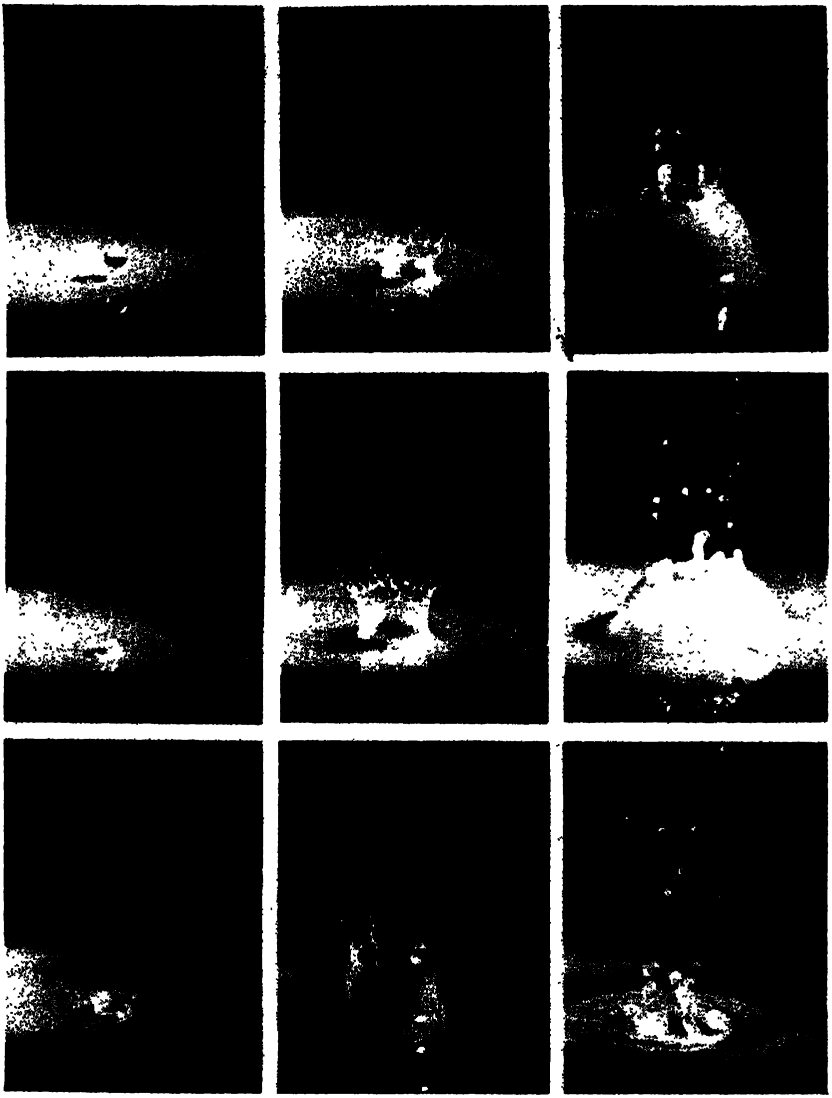


Figure 3-1. Raindrops striking shallow water throw up geyser-like eruptions. This splashing and churning of shallow water keeps it stirred up. It gives the power needed to keep soil particles from settling out while they are being floated off the field. These are falling on shallow sheets of water from a height of 7½ feet. Read down from top of left-hand column, then from top of the middle and right. This chart represents different stages of a single splash. (Naval Research Laboratory Photo)

For a long time we didn't know that raindrops made water in the field muddy. We thought of their patter on the roof and their refreshing plants after dry spells, and we thought that they brought only good tidings. We believed that the water flowing over the surface of the ground cut the soil loose, and it was this soil that made it muddy. We knew flowing water could move soil, so we assumed it could tear it loose, too. As a result, we built terraces or walls to keep it from eroding our soil. From recent studies we know now we should have paid more attention to raindrops and what they are doing to our soil. We know we should have built roofs of plant cover over our fields, because we need them there, as well as walls around and across them.

We knew a lot of our terraced land was destroyed by erosion and noticed that terraced land eroded about as fast as unterraced. In time, some of us began to wonder if terraces did what we thought they should. We even wondered whether or not we actually knew how water erodes our soil. As a result, a few of us decided to take a look at raindrops to see if they did anything to our fields. We found they

Figure 3-2. The splash caused by raindrops falling on bare ground starts the water erosion process. This splash was caused by a drop of water falling on damp soil from a height of 7½ feet. Falling raindrops blast holes in the ground like bombs. The flying particles are a mixture of mud and water. (Naval Research Laboratory Photo)

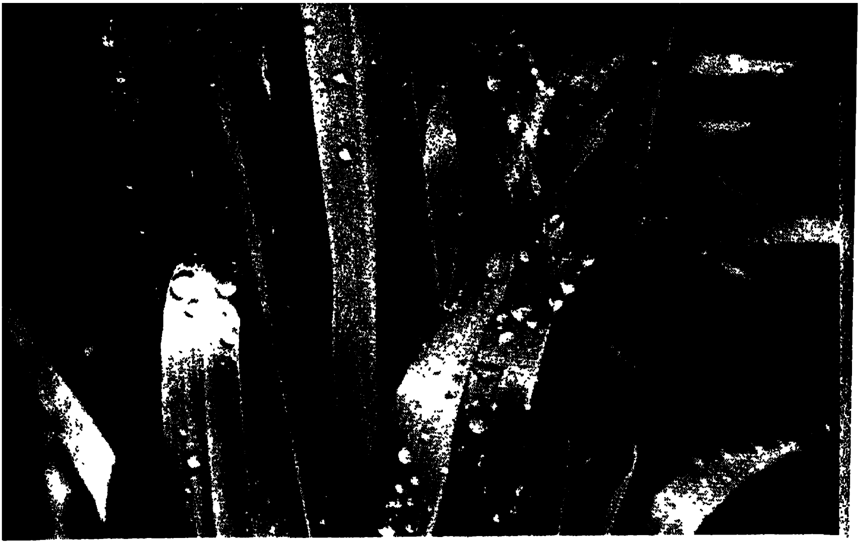


Figure 3-3. Dense, low-growing plants intercept the falling raindrops. This relieves the drops of most of their energy before they reach the surface of the ground or the surface of flowing water. This, in turn, preserves the open, porous nature of the soil and prevents the surface flow from being made turbulent. The water remains clear and is absorbed more freely by the soil. (Soil Conservation Service Photo)

splashed lots of soil when they struck bare ground, but that they didn't do so when they fell on fields covered with plants.

With this information, we became more interested in what the raindrop did and looked to see where the soil went after it was splashed by raindrops. We found the ground covered with a shallow sheet of water during hard rains. The splashed soil fell into this sheet of water, and, as the water moved down hill, it took our soil with it.

This was something new. We didn't know about such action of raindrops: We didn't know they splashed soil in our fields. Neither did we know that falling raindrops and shallow sheets of water formed a team. We never imagined this was how water actually eroded soil and became a part of the erosion process. This made us think we might be mistaken about surface flow.

We wondered if we didn't need to catch the falling raindrop by building a roof over the field with plants. Maybe a roof was what we needed. We wondered if we needed walls and roofs, too. We knew that walls didn't check falling raindrops, because falling raindrops strike from above. To check them we needed roofs.

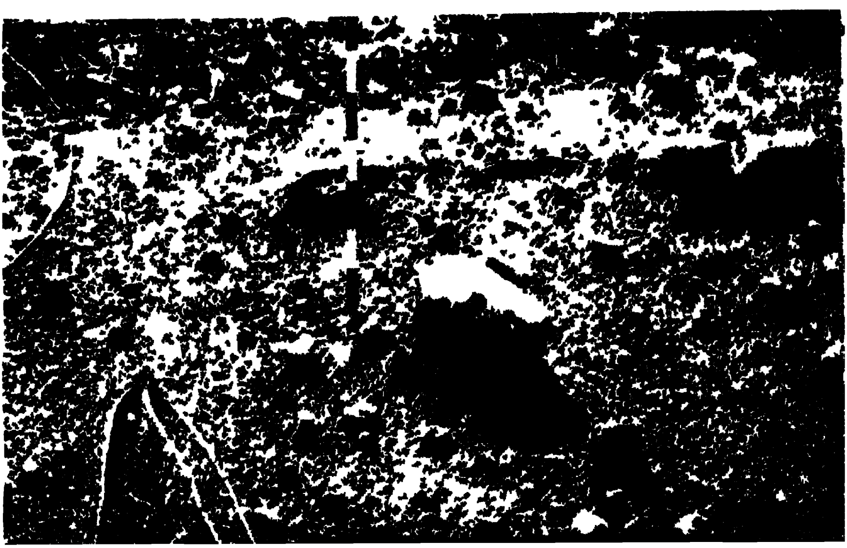
When we discovered that raindrops moved lots of soil, we took

another look We wanted to see what really did go on in our fields when it rained In taking this look, we found out other things we didn't know before Previously, we thought water flowing over the surface of the ground was our main enemy You can imagine our surprise when we found that the falling raindrop was the chief culprit and flowing water was only his assistant

We found that either flowing water or falling raindrops could erode soil Each can erode soil without the aid of the other but we found most soil was moved when they acted as a team Raindrops blasted soil particles loose, flowing water swept them downhill

We found raindrops and flowing water acting like a pick-and-shovel crew loading a truck Raindrops represent the pick-and-

***Figure 3 4** Both raindrops and flowing surface water are complete erosive agents in themselves In one phase of the erosion process they work together as a team This teamwork occurs before the surface flow concentrates to form streams or to flow in channel Falling raindrops blasted the soil loose on this South Carolina field The blasted material fell back into the shallow film of water on the surface of the ground and was floated downhill The columns of earth beneath the stones and the thin walls of earth beneath the plant roots in the left foreground show that the force which tore the soil loose was applied from overhead It was applied by falling raindrops and not from the side by flowing surface water About two inches of soil was removed from this field during one rain Even the sparse plant cover in the background was sufficient to prevent serious erosion* (Soil Conservation Service Photo)



shovel crew. Flowing water is the truck. Falling raindrops pick or blast soil loose and throw it into flowing water, the truck. Flowing water then carries the soil downhill. This is shown in Figure 3-4.

This discovery made us want to know more. We wanted to know the exact part raindrops played, and the part played by flowing water. We wanted to know how much of the soil carried from our fields was blasted loose by raindrops, and how much was torn loose by flowing water.

We made some tests, in both the laboratory and in the field. We worked with water drops from artificial rain makers and with natural rain. The findings from our many tests and comparisons were checked carefully. Again you can imagine our surprise. We found flowing water tore loose less than 10 per cent of the soil moved from our fields, in most cases, it was less than 5 per cent. In other words, we found that about 95 per cent of the soil eroding from our fields is splashed up by falling raindrops.

The thing that pleased us most was that we found the answer to man's failure to protect his soil. Without knowing what raindrops did, it wasn't possible to save our soils. We know now why our soils continued to erode after being terraced. Thinking our enemy attacked from the sides, we built walls when we should have built roofs. Our main attack was from above, so we were fully exposed to our attackers and didn't know it.

Our findings showed us new and better ways to protect our soil, and they made our task a lot more interesting too. We know now what we must do to keep our soil from eroding. Our findings also show us how to improve our soil so it will grow bigger and better crops.

This information is important to us all, it is felt that you'll be glad to know about it, too. But before going further we should understand we can't have erosion without force. Force must be applied to the ground to tear our soil particles from the surface, just as you must apply force to knock a brick out of a wall. In water erosion this force is applied by falling raindrops and flowing surface water, but most of it is applied by falling raindrops.

RAINDROP'S DOUBLE LIFE

You can see the raindrop leads a double life—one is gentle and refreshing; the other is explosive and destructive. The first is repre-

sented by the gentle patter of raindrops on the roof. They refresh our plants after dry spells. The other is represented by the explosive and destructive action; this occurs when falling raindrops strike bare ground.

The amount of force with which a raindrop strikes the ground varies, depending on its weight and speed. Large drops containing more volume of water than small drops, weigh more. Consequently, large drops have more force than small drops traveling at the same speed. The total amount of force applied to our ground during rains is enormous. It is several thousand times that applied by runoff water; in many cases, it is over one hundred thousand times as great.

RAINDROPS ARE BOMBS

At this point, we should stop thinking of raindrops as being gentle and refreshing and think of them as being explosive and destructive. We should liken them to bombs, which they really are. In many ways falling raindrops are like bombs. They are enclosed in a skin, or shell, which is in the form of a surface film. The surface film is tight enough to keep the water in the drop and to keep it from flying apart on its way down. The same is true in the case of a bomb—the shell, or skin, keeps the explosive material in until it explodes.

You can see how this film works. When you put a few drops of water on a piece of waxed paper, or on a greasy spot, it won't spread or wet the surface. Instead, it pulls itself into small round balls about the size of BB shots. The raindrop has about this same shape as it falls through space, except it is a little flat on the bottom. (See Figure 3-1.)

A raindrop explodes like a bomb when it strikes bare ground. (See Figure 3-2.) When it first hits the ground it makes a dent, as you would if you hit the ground with a hammer. The ground soon checks its downward movement. Now, the force of the drop shifts to the outer edge, exploding the surface film enclosing the water. It explodes in the same way you explode a paper bag.

The force released by explosion of the raindrop spreads outward. It spreads until it reaches the walls of the dent it made when it first hit the ground. It then turns upward and throws a lot of muddy slush. It acts like any other bomb: When it explodes on the ground, it knocks out a hole or crater. When raindrops strike level ground, this slush is thrown evenly in all directions to spread over the surface.

Figure 3-5. Fertility erosion on a cultivated field in New Jersey. Organic matter, silt, and clay were splashed from the sand by raindrops. The washed sand, appearing as light-colored deposits between the rows, was left in the furrows. This process removed 60 per cent of all the phosphoric acid applied to a level sandy soil in Alabama over a 26-year period. (Soil Conservation Service Photo)

But when raindrops strike the sloping land surfaces, it is a different story. Large amounts of the soil are moved downhill by raindrop splash.

The level land may have little soil loss, but that doesn't mean the soil is not damaged. It is. Large amounts of the plant food are lost, and much of the organic matter, silt, and clay is floated away. These are the materials that hold the plant food. Some of the muddy water may settle in low places. Some of it drains into openings. The New Jersey field in Figure 3-5 shows how this works.

Falling raindrops aid erosion in another way. They keep standing water churned up and give it more lifting or moving power. When raindrops fall in shallow water they churn it up the same way you do when you throw small stones in water. The water jumps up and down and becomes choppy. This churning motion gives water more lifting power to carry soil particles. It keeps small soil particles afloat and keeps them from settling out. The particles float off the field with the water.

Even good-sized pebbles can be worked downhill this way. Rain-

drops bounce them off the ground when they strike shallow water, and the flowing water moves them somewhat before they settle. This constant bouncing and moving works the pebbles downhill.

FLOWING SURFACE WATER

Flowing surface water has two types of power—one is used in carrying or moving the soil; the other is used to tear the soil loose from the ground. Water flowing in shallow sheets has only one type of power—moving power. It can pick up loose soil grains lying on the surface and carry them downhill, but it can't tear the soil loose. It can only move what is already loose.

Flowing water acts like you do sometimes. You can pick up a small tree and carry it, but you couldn't pull it up because you aren't strong enough. You have enough strength to carry it but not enough to pull it up. Shallow sheets of water can move loose soil, but they can't tear soil loose. They aren't strong enough.

You can demonstrate the carrying or moving type of power. Smear some mud on your sidewalk or a board. Then attach your garden hose to the faucet and adjust the nozzle to let water flow out in a weak stream. On its up side place the nozzle on the pavement a few inches away from the mud, so that the water will flow toward the mud. Let the water flow gently over the mud for a while. See? The water won't cut the mud loose because it does not have enough power. It will pick up loose grains and carry them away though, since it has moving power but no cutting power.

Now adjust the nozzle to spray drops, using drops about the size of raindrops. Point the nozzle upward and let the water drops fall on the mud. See how quickly the drops splash the mud loose

Flowing water can't tear our soil loose until it gets scouring or tearing power. It can't get scouring power until it gets a tumbling or swirling motion. It has to stop flowing smoothly and get agitated or stirred up. Shallow sheets of water don't get stirred up—they can't.

To get a tumbling or swirling motion, water must pile up and form deep sheets. It can't pile up on level surfaces, but must collect in low places such as grooves or trenches. It must get in a ditch or channel to form streams.

Water flowing in streams has scouring power, so it can tear soil particles loose from the soil. It has both types of power—tearing

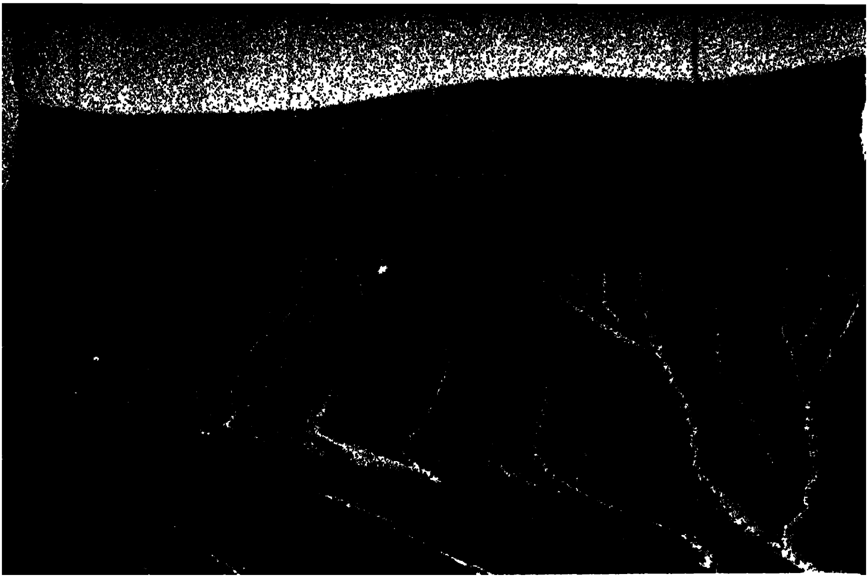


Figure 3-6. Flowing surface water produces widely different effects from falling raindrops. Flowing water tends to collect in channels—first, in rills, and then, as these small channels converge, in streams. Surface flow cuts channels and eventually gullies, as in the California field shown here. (Soil Conservation Service Photo)

particles loose and moving them, too—and it does both at the same time.

You noticed we said flowing water didn't get scouring power until it formed channels. It becomes channelized, and it can't tear the soil loose until such a process occurs. This also means that flowing water erodes the soil only after it gets into channels. It scours soil loose from the bottom and sides of channels and ditches, but it can't erode flat surfaces in the fields. It doesn't have scouring power while flowing over broad surfaces in shallow sheets.

Flowing water doesn't get tumbling motion until it collects in channels, and it can't scour until it gets tumbling motion. It can't scour until it gets in channels, so flowing water does its eroding in channels and no other place.

Falling raindrops erode our soil on broad surfaces. They also erode channel banks, where banks are exposed to them. Erosion occurs on our soil any where we leave it bare—on broad surfaces or in channels. Now you can understand why at least 95 per cent of the soil eroded from our fields is the work of falling raindrops. You can clearly see that our job is to keep falling raindrops from striking our

bare soil. It is as simple as that. It is not going to be easy for us to do though, *but that is our job. We must find a way to do it.*

OTHER DAMAGE FROM RAINDROP SPLASH

Splash erosion causes three types of damage: (1) puddle erosion, (2) fertility erosion, and (3) sheet erosion.

Puddle erosion. As previously stated, falling raindrops do enormous damage to our soils. They beat on our bare soil during violent storms, shatter clods and soil crumbs, and break down the soil structure (crumbs) into a puddled condition. The beating and churning action of these drops compacts our soil's finely broken parts into a nearly impervious layer of surface mud. This compacted surface layer is made denser and more nearly impervious with muddy rainwater. Rainwater filters into our soil, and, eventually, the open spaces in this surface layer are filled with this mud. This damage shows as crusts on bare fields. The surface is glazed like the icing on a cake.

You can demonstrate the puddling process by playing a heavy spray from a garden hose on bare ground. You can see puddling taking place on the surface.

Figure 3 7. *In addition to splashing muddy slush into the air, falling raindrops compact the surface layer of soil. The beating and churning action of these drops compacts the soil's finely broken parts into a nearly impervious layer of surface mud. In this South Carolina field the mud is glazed like the icing on a cake.* (Soil Conservation Service Photo)

Figure 3-8. Organic matter, silt, and clay were blasted from higher up the slope and deposited in low spots and depressions in this Ohio cornfield. This 4½-inch thick layer was laid down by one rain. This is the chief source of loss of organic matter from cultivated land. (Soil Conservation Service Photo)

Our ground covered with plants is not damaged, because the plants catch the raindrops. The drops do not strike the surface, and our soil keeps its natural structure. Water that accumulates on the surface remains clear. It soaks into the ground with ease. Water from raindrops broken up by plant cover moves slowly down through plant cover to the ground and does not disturb the soil surface. The water is clear. It does not fill the open spaces with mud when it soaks into the ground.

Plant cover prevents puddling. Because plant cover catches raindrops, they don't strike bare ground directly. Instead, they are broken up by the plant cover, and the broken parts are eased to the ground. They do not disturb the soil, so the soil keeps its crumb-like nature. It remains in better shape for our crops, which will give bigger and bigger yields.

Puddle erosion decreases infiltration. When our soil becomes puddled it can't absorb water. The surface of the ground is packed, and water can't get in because the soil surface is sealed. Water and

air can't get in to supply plant needs, so our soil loses much of its ability to grow crops.

Fertility erosion. Plant food in our soil is in the organic matter and silt and clay. Organic matter is plant parts. Most of it is rotten, light, floats easily, and is in the surface soil. It is in the soil first splashed by raindrops, and is floated away. Silt and clay are the smallest soil particles we have. They are not light as organic matter, but they are very small. They are held up in water, and splashed out of our soil with the organic matter. They also float away with it, leaving our fields poorer. Subsequently, not as good crops are grown from them.

Plant food is removed from our soil everywhere raindrops strike bare ground. It doesn't make any difference if the surface is level or sloping. Some of the organic matter and fertility-bearing elements of the soil are floated away.

You can demonstrate fertility erosion. Put a spade full of soil in a bucket or tub. Run a constant stream of water into the vessel from a garden hose. Stir the muddy mixture with a stick. The overflow carries out the organic matter and silt and clay. Soon, nothing is left in the bottom of the tub but coarse sand.

Figure 3-9. Soybeans were planted on this Posey County, Indiana, farm in 1938. The silt in the foreground was brought down from higher up the slope by one heavy rain. (Soil Conservation Service Photo)

Sheet erosion. Sheet erosion is actually splash erosion. Splashing raindrops wear soil down evenly over the surface. They remove soil in thin sheets, as you wear down a surface of a board by sandpapering it. Raindrops sandpaper the surface of our fields.

Figure 3-10. Plant cover, or mulch, prevents puddling of the surface layer of soil and maintains a high infiltration rate. The cups on top of the jars were filled with equal amounts of the same soil. A mulch of grass clippings was placed on top of one; the other was left bare. Water from a garden hose was played on the soil for seven to eight minutes to simulate rain. The bare soil became puddled and little water percolated into it. But the mulch preserved the open structure of the surface soil and water percolated into it freely. (Soil Conservation Service Photo)

You can demonstrate the effect of splash erosion. Put a small pile of sand out in the open. When it rains, the sand pile will be flattened out. Raindrops work about the same way on our hills, by bringing down material from the top and dumping it lower down. The force of the splashing raindrops is applied uniformly. It is the same over

Figure 3-11. Even though the land is level, as on the Illinois farm in this picture, much of the organic matter and fertility-bearing elements are lost. The fertility-bearing elements in the exploded particles of soil are floated off the field. Some of the muddy water may settle into pockets or drain into openings in the soil. When the sun comes out, the surface mud bakes into an almost impervious crust. When this crust is broken, it is so fine it is easily carried away by the wind. (Soil Conservation Service Photo)

Figure 3-12. Gullies formed in a winter wheat field in Oregon. The small amount of cover provided by the young wheat plants held splash erosion to a minimum over most of the field. Active erosion really did not start until the water concentrated to form channelized flow. Between the gullies the water moved in prechannel stages, or shallow sheets, and did not erode the soil as much. (Soil Conservation Service Photo)

the area on which the rain falls. It causes the most soil movement at the top of our hills, for here the least amount of force is needed to blast our soils loose.

Figure 3-13. *The effects of raindrop splash in the erosion process frequently are most pronounced on the short, steep slopes near the crest of hills, as shown in this picture taken in Michigan. Under such conditions falling raindrops are most effective in moving soil downhill without much assistance from flowing surface water.* (Soil Conservation Service Photo)

DEPOSITION OF SOIL

Soil materials deposited by moving water are usually separated by particle sizes. Being the heaviest, the large particles are the first to be deposited. As the velocity or rate of flow slows, water loses some of its carrying capacity. Smaller particles are dropped. Further reductions in velocity results in the next-size particles being dumped. Organic matter and silt and clay particles are light, so they are the last to be dumped. They are carried the furthest downstream. These fine and light materials are often floated miles downstream and frequently dumped in our reservoirs.

Exercises

1. Fill a shallow pan or box level full with soil. Scatter a few flat stones, coins, or discs over the surface. Take a garden hose and play water on the soil from five to ten minutes to simulate rainfall of moderate intensity. Explain how the pedestals you find under the flat objects were actually formed.

2. Smear some mud on the sidewalk or a slightly tilted board. Take a garden hose and try to remove the mud by letting water flow over it. (Do not direct the full force of the hose stream at the mud as you do when you are flushing a sidewalk; instead, let the water flow.) Smear another batch of mud on another part of the sidewalk or another slightly tilted board. Play water on this portion of the mud from a garden hose to simulate rainfall of moderate intensity. Which method removed the mud the quicker? Why?

3. Fill a tub or a bucket with water. Put a spadeful, or two, of sandy soil in the vessel. Take a garden hose and run water into the vessel just fast enough to cause a slight overflow. Take a stick and stir the soil vigorously for from five to ten minutes. Examine the soil remaining in the bucket. What change has taken place? Why?

4. Line two funnels with clean filter paper and place in racks. Pour clean water into one of the funnels and water that has been made muddy, by stirring some clay soil into it, into the other funnel. What happens? Explain how this action compares with that of puddle erosion.

Questions

1. In what ways have we been mistaken in how water erodes soil?
2. What evidence have you seen to show raindrops splash soil? What does this tell you about raindrops and erosion?
3. How does most of our soil get off the field during rains?
4. Which is the more important in water erosion, falling raindrops or flowing water? What is their relative importance?
5. Why does our soil continue to erode after being terraced?
6. Why is force needed to tear soil loose? How is this force applied? How does the force applied by raindrops compare with that of runoff water?
7. In what ways is a raindrop like a bomb?
8. Describe what happens when a raindrop strikes the ground.
9. What happens to the splashed soil when hard rains fall on bare level ground? When they fall on sloping land?
10. How do falling raindrops give standing water more power? How does this aid in soil erosion?
11. How many kinds of power does flowing water have? What kind of

power do shallow sheets of water have? What kinds of power does water flowing in channels have? How does flowing water erode soil?

12. Why can't shallow sheets of water flowing over broad surfaces erode soil?
13. Where and how do falling raindrops erode soil?
14. Explain how crusts are formed on cultivated land. Why is it that ground covered with plants does not form crusts?

4

How Wind Erodes Soil

CONDITIONS where wind erodes soils differ from those where water operates. Wind, unlike water, will not erode damp or wet soils; however, wind is like water in one respect: It cannot erode soils that have a good plant cover. This cover may be in the form of cultivated crops, grass, weeds, mulch, or other types of plant materials.

Wind erodes soil more often in areas of light rainfall. Here, the surface of the ground is dry, and is often unprotected from the wind. Due to low rainfall, plant growth may be light or absent. Wind sometimes blows soils in areas of heavy rainfall, but these soils are sandy or peaty. They dry out quickly and have little plant cover, so wind can move them easily.

HOW WIND MOVES

We think of wind moving in one direction—straight ahead. Actually, wind moves four ways simultaneously. Wind does have one movement that carries it straight ahead, which we call forward movement, but the other three movements occur within the forward movement. Figure 4-1 shows the forward movement of wind.

In one of these movements, wind spins around top-like in the shape of a funnel. The spinning movement we call eddies. Part of the wind moves in sharp blasts or sudden puffs. The puffs are like the ones you make when blowing out a candle. We call this movement gusts.

Wind moving in eddies does not go straight ahead but cuts across the path of the forward movement. It moves like you do when you

Figure 4-1. The first dust storms are the most destructive. It is during this period that most of the organic matter, silt, and clay particles are removed from the field. This Oklahoma dust cloud is called a "black roller," and the photo shows its straight ahead movement. It is one of the first dust storms for this field. The air is heavily laden with organic matter, silt, and clay. (Soil Conservation Service Photo)

wade across a stream. You cut across the current, the stream's path. Wind moving as gusts may travel with the forward movement or across its path. The main thing is that it moves in sharp blasts.

When these sharp blasts cross the path of eddies a fourth movement is started. It is a tumbling or swirling movement and acts like a group of boys and girls when some of them are spinning around on one foot and the others turning cartwheels. However, in the case of wind, it gets all mixed up and looks like it is being stirred with giant eggbeaters.

It keeps the whole body of air in a constant turmoil. This is illustrated in Figure 4-2.

You can see these types of wind movement on any windy day. Build a small fire outdoors. Watch how the smoke moves in the direction the wind is moving. But no matter which side of the fire you stand on smoke gets in your eyes. This is because wind moving in eddies cuts across the path of the forward movement. It finds you no matter where you are.

Now and then you will be almost blinded by a sudden puff of smoke caused by gusts. Sometimes smoke from gusts rolls in a swirl-

ing movement, like broken waves. This happens when the sharp blasts cut across the path of eddies. Each of these four wind movements has a part in causing the dust cloud and wind erosion.

HOW WIND MOVES SOIL

Eddies, or the spinning movement of the wind, start soil moving. Wind moving in eddies travels much faster and has more power than the forward movement. It keeps up with the forward movement and spins, too. This spinning motion twists sand grains out of the ground. The column of air in eddies extends upward. When sand grains are twisted loose by the spinning movement, they are lifted straight up. Gusts drive eddies at a faster speed, also push loosened sand grains forward, and keep the air in a turmoil. This turmoil keeps dust afloat once it is kicked off the ground.

Figure 4-2. High winds are capable of lifting and transporting for great distances large quantities of the organic matter, silt, and clay fractions of the soil—the life-giving substances of the soil. This sorting process added to the general sandiness and low productivity of this Colorado field. (Soil Conservation Service Photo)

Forward movement determines the direction the main body of air moves and also governs the direction loosened soil particles take. These four wind movements, acting together, move soil particles in three different ways, which are known as saltation, suspension, and surface creep. All three movements are usually occurring at the same time.

Movement of soil by saltation. Most soil carried by wind is moved in a series of short bounces that is called "saltation." Soil grains moving in saltation are started by eddies, which lift them straight up. When they leave the ground, the forward movement of the wind pushes them along at the same time. The loosened soil particles rise until the pull of gravity overcomes the lifting power of the wind. Then, they fall to the ground just as you would if you fell from a tree, or stepped into space off a ladder.

The soil particles strike the ground hard. If they don't sink into the ground, they are lifted back into the air, and repeat the movement. They act like rubber balls, bouncing up and down. Each time they strike the ground, they kick smaller particles into the air.

Some grains rise only a short distance, and others leap 1 foot or higher. The height they rise depends on how hard they were jerked off the ground. They are also pushed forward by the forward movement of the wind. When they strike the ground, they either bounce up and repeat the movement or strike other grains. The grains they strike may be bounced up or pushed forward on the ground. Those failing to bounce sink into the ground and become a part of the movement in surface creep.

The height a grain rises is due to two causes: one is the spinning of the grain, the other is the force with which it was lifted off the ground. More than 75 per cent of the bouncing grains spin at a speed of 200 to 1,000 revolutions per second. The distance a grain moves forward is about four times the height it rises off the ground. Most soil grains moving in saltation remain within one foot of the ground. A few rise higher.

Movement of dust in suspension. Fine dust particles are kicked up by bouncing action of grains in saltation. When bounced off the ground, they are caught up by swirling wind. They are small and light in weight. The lifting power of the wind on them remains greater than the pull of gravity, so, they are lifted higher and higher and are carried along with the wind. This method of moving soil is known as "suspension movement."

Dust particles carried in suspension make up a good proportion of the total soil carried. The method by which fine dust is lifted from the ground differs from saltation. Particles moving in saltation are lifted off the ground by eddies. Particles carried in suspension are bounced off the ground by the bouncing of grains moving in saltation. Movement of dust is a result of saltation. Without saltation, dust clouds would not form.

Dust moving in suspension is controlled by wind movement It is taken to great heights, often carried long distances, and is lost from the field On the other hand, soil moved in saltation and surface creep usually remains within the eroding area.

Movement of soil in surface creep. Sand grains too heavy to be lifted off the ground by eddies are pushed along the surface. This is done by blows from bouncing grains, a movement we call "surface creep." Grains moving in surface creep are driven by blasts from other grains To be picked up by eddies, soil grains must stick up above the ground level slightly They must also be light enough for wind to lift

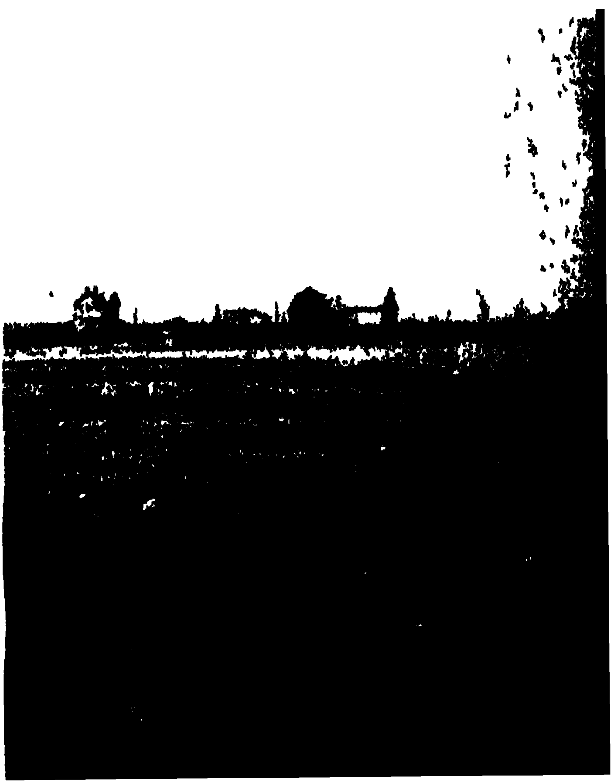


Figure 4-3. Wind acted as a fanning mill to remove the organic matter, silt, and clay from this South Dakota field, leaving sand and gravel. (Soil Conservation Service Photo)

Grains smaller than those picked up by eddies are too small to stick up above the surface. The wind can't get a hold on them—they have to be bounced off the ground.

Grains larger than those lifted by eddies do stick up above the surface. Wind can get a hold on them, but can't lift them because they are too heavy. They are pushed and shoved along the surface by blasts from bouncing grains. Once bounced into the swirling wind, small dust particles float in the air and drift with the wind.

WIND ACTS LIKE A FANNING MILL

Wind acts like a fanning mill on the soil. It sorts out light organic matter and clay and silt particles, as your mother separates flour from lumps by running it through a sieve. This lightweight material is blown away. The heavy sand grains are left on the field, as wheat is left when the straw and hulls are blown away by wind. (See Figure 4 3.)

DUST STORMS TAKE AWAY PLANT FOOD

Small silt and clay particles serve as the soil's pantry for storing plant food. If these small particles are blown away, soil has no place to store plant food, just as removing the pantry from your kitchen

Figure 4 4 The portion of this Colorado field in the foreground was blown out to a depth of more than twelve inches during a single dust storm. The organic matter and small lightweight silt and clay particles were blown away. The sand and coarser materials were blown into drifts and dunes. (Soil Conservation Service Photo)

leaves no place for your mother to store your food. The big difference between the soil's pantry and the one in your kitchen is that your mother can get another one—the soil can't. The soil could no longer store food for your crops.

Figure 4-5. Plant cover is effective in controlling soil drifting because it can trap the soil moving in saltation. The cotton stalks to the right on this California field trapped the sand moving in from the field to the left. The cotton stalks also prevented the wind from picking the sand up again. (Soil Conservation Service Photo)

To make things worse, the plant food already stored in the soil's pantry is blown away, too. It seldom happens that all small silt and clay particles blow away during a single storm; instead, some goes with each storm. As a result, the soil has less and less plant food left after each storm, and the soil gets poorer and poorer. Eventually, it won't have enough plant food to grow good crops.

Wind erosion in some respects is like an epidemic disease. It must be controlled where it first starts, because it gets worse as it spreads. That means we have to stop saltation when it first starts.

Most of the soil moved by wind in many fields is sand, but the sand remains in the field. It is merely shifted from one place to another. The sand can't hold plant food or won't grow good crops.

Some soils are made up mainly of silt and clay particles. In such cases, the whole soil body may be blown away during severe dust storms. (See Figure 4-4.)

ONLY DRY SOILS BLOW

Only dry soils can be blown by wind—wet or damp soils can't be moved. Neither can wind move soil that is protected with a good plant cover. Plants slow down the speed of wind at the ground surface, so that the wind is not strong enough to start soil particles bouncing.

Soils made up mostly of dead plant material (called "peat and muck soils") blow away easily. The rotted plant material is broken into small pieces that are light in weight and blow easily.

SOME WINDS CAN'T MOVE SOIL

All winds do not blow soil. Some winds can't blow soil, even in places where dust storms are common. In one way, winds are like boys. All boys do not have equal strength. Large boys are usually stronger than small boys, so a large boy can lift more than a small boy.

With the wind, it is the speed of travel that determines its strength, its lifting power. Slow winds have less power than fast winds. In order to lift soil grains, winds must blow a minimum of eight to nine miles per hour at 6 inches above the ground. Winds blowing slower than this can't move soil.

WHY WIND UNLOADS SOIL

Wind moves soil because it has power enough to do so. It gets this power from speed and turbulence. The lowest speed that will start soil grains moving has already been mentioned. Wind moving at lower speeds can't move soil, and wind carrying soil dumps it if its speed is reduced to or below this speed. It doesn't have the power to keep soil grains moving, neither does it have power to pick them up after depositing them.

During dust storms, wind is continually picking up and putting down sand grains. It has power to pick them up and carry them, but

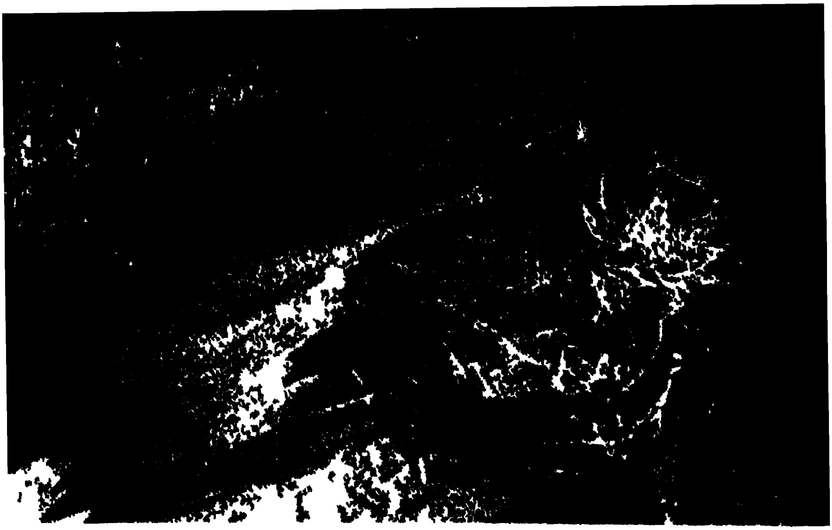


Figure 4-6. Objects that reduce the velocity of soil-laden winds cause them to deposit their load The soil deposited along this Texas fence was blown from the cultivated field on the right Notice the absence of wind erosion damage on the field to the left The cotton stalks and sorghum stubble reduced the velocity of the wind to the point where it could not start the saltation movement (Soil Conservation Service Photo)

if its power is reduced enough it can t pick up soil grains When it unloads what it is carrying, the storm is over The wind can't get soil grains moving again

The velocity of the wind is the key to soil movement by wind Keep wind velocity below the danger point at the surface of the ground, put obstructions in its path, and slow it down Plant cover is what nature uses to keep wind velocity down

Because of their retentive ability, plants are particularly effective in controlling drifting of material moving along the surface in a series of short leaps Clumps of plants in areas of moderate sand drift will collect blown material around them They form small mounds or dunes, and, as the sand heap grows, the plants, if adapted to sandy soil, also grow They continue to accumulate soil until a heap several feet high may be formed (See Figure 4-6)

Exercises

1. Build a fire from small sticks or leaves out in the open on a day when the wind is blowing at a moderate velocity. Notice that no

matter where you stand around this fire smoke is blown into your eyes. Even though the main current of wind is blowing in one general direction, the cross currents, caused by gusts and eddies, blow the smoke in all directions. It is this turbulence created by gusts and eddies that enables wind to erode soil.

2. Take some dry sandy soil and an electric fan. Turn on the fan. Pour the sand out of a bucket so it will fall in front of the fan. See how the wind sorts soil grains on basis of size. The light ones will be blown away; the heavier ones will fall to the ground.

Questions

1. How do conditions favoring wind erosion differ from those favoring water erosion?
2. How has man affected wind erosion? How did he do this?
3. Name the four types of wind movement. Describe each.
4. How is soil movement started by wind? Which of the wind movements starts soil moving?
5. What part does the forward movement play in soil movement? What part do gusts play?
6. Describe how wind actually moves soil. What is saltation? Suspension movement? Surface creep?
7. What determines whether soil grains move in saltation, suspension, or surface creep?
8. Why is the loss of organic matter and silt and clay from your field important to you?
9. Why is the saltation movement so important? What meaning does it have in controlling wind erosion?
10. Why can't wet or damp soils be blown by wind?
11. Why can't all winds move soil?
12. How does the slowing of wind velocity affect its load? Why is this true?

5

Soil Crumbs

While strolling in the woods or pasture did you notice how soft and springy the earth was? Did you notice how different the soil was there from that in the corn or cotton field? Instead of being soft or springy, the soil in the corn or cotton field was firm and hard.

If you picked up a handful of soil from the woods or pasture, you noticed it was loose and fluffy. It was easy to stir and pleasant to feel. On the other hand, soil from the corn or cotton field was hard and firm. It was difficult to stir and was not pleasant to feel.

To see why the woods or pasture soil was different from soil in the corn or cotton field, pick up a handful of soil from the woods or pasture and let it spill through your fingers. Notice the grainy, crumb-like structure, which is made up of little clods. Those little clods make it soft and springy when you walk on it, and they also play an important part in the crops you raise.

Now compare the soil from the woods or pasture with soil from the corn or cotton field. The soil from the corn or cotton field will be firm and hard and won't have any crumb-like particles. When you plow it, the clods are large and lumpy.

The difference you feel in these two soils is due mainly to soil crumbs or aggregates. These aggregates are the little clods, the particles that run through your fingers. Woods and pasture soils are apt to have a good structure, lots of aggregation. Cultivated soils may have very little or none at all.

Those aggregates or crumbs make the soil more suitable for raising your crops and make it easier for water and air to move

Figure 5-1. These two handfuls of soil were taken just across the fence from each other in Illinois. The one on the right came from an area in bluegrass sod. That on the left came from a cornfield. Those "little" clods or granules in the sample to the right are aggregates. Lots of aggregates mean good tilth. Few or no aggregates mean poor tilth. The soil from the cornfield breaks up into large, hard lumps or clods. (Soil Conservation Service Photo)

through the soil. This free movement of water and air aids the growth of soil microbes, which are low forms of plant and animal life. They feed on dead plant parts, and, in turn, affect both the amount and condition of plant food. Soil aggregation makes for a grainy, more porous soil—one that drains better, absorbs water faster, and has less water runoff.

SOIL FERTILITY IS MORE THAN PLANT FOOD

Too often we think of our soil fertility in terms of plant food or soil nutrients. Actually, nutrients are only part of the crop-growing problem. There are many cases where soils that contain all the plant food needed to raise or produce big yields *do not produce those big yields.* They don't produce them because soil structure has broken

down. As a result, crops are not able to make best use of the plant food in the soil, even though the needed plant food is plentiful.

Only when the soil breathes, only when air and water can move freely to make the necessary food elements available to plant roots, will we get the highest yields that the soil is capable of producing.

GOOD SOIL STRUCTURE

Virgin—never cultivated—prairie and forest soils probably had about the best structure (lots of aggregates) it is possible to have. This structure was developed by hundreds of years of continuous grass and trees. It was a porous, granular structure; one that permitted free movement of air and water. It absorbed the rains readily, and plant food in the soil was freely available to plant roots.

The movement of air made possible by the granular structure

Figure 5-2. The soil under the bluegrass sod along the highway is full of aggregates. It is in good tilth. The handful on the right in Figure 5-1 came from this bluegrass sod area. The corn just across the fence is on the same type of soil: Flanagan silt loam. At the time it was put into cultivation it too had good tilth. But now it has very few aggregates. It is in poor tilth as is illustrated by the handful of soil on the left in Figure 5-1. (Soil Conservation Service Photo)

encouraged the growth of soil microbes. They flourished, aiding the decomposition of organic material and helping to add nitrogen to the soil. It was this granular structure that made our virgin prairie and forest soils productive. True, they were well supplied with plant food, that was part of it. But it also took soil aggregation—a structure that made the nutrients ready or available for plant use and held the needed moisture—to produce top yields.

It may not be practical to maintain this high level of soil structure on our farms today. The soil structure that was built up by hundreds of years of grass and trees can be maintained only by continued growing of grass and trees. We can't crop our land without destroying some of this structure. On the other hand, we can't afford to forget the importance of good structure. Even though we maintain fertility in the chemical sense, our soils won't stay productive if we allow structure to break down too far.

HOW SOIL AGGREGATES ARE FORMED

How can we maintain structure that will give us high protection along with full use of our land? To do this, we must understand how soil aggregates are formed. What causes these small soil particles to stick together? What things will prevent the formation of

Figure 5-3. This is the cornfield shown in Figure 5-2. Its clods are hard and lumpy. It is in poor tilth, having few or no aggregates. (Soil Conservation Service Photo)

soil aggregates—break down soil structure? Finally, we must adjust our farming practices to get as much aggregation in our soils as possible, along with heavy cropping.

Soil grains are grouped into aggregates by the action of complex sugars. One portion of the sugar arranges the soil particles loosely into clusters. Another portion of it is like a gum. It binds these soil grains firmly into crumbs or aggregates. The soil grains must be grouped loosely into clusters before they can be bound together into stable crumbs or aggregates. One portion of the sugar groups soil grains loosely into clusters. It does it the same way lime does when dropped into a bottle of water made muddy by putting clay in it and shaking. Before the lime is used, the clay particles repel each other. They remain separated as far apart as possible. They are light and stay suspended in the water. The water remains muddy.

The action of the clay particles is governed by another of Nature's laws. It is a very simple law, but we must know how it works if we wish to know how aggregates are formed. The law, stated in the simplest terms, is: Particles of like charges—electrical charges, plus or minus—repel each other, particles of unlike charges attract each other.

Let's explain this with an illustration. Clay particles are negatively charged (a minus charge), so they repel each other. They get as far from each other as the water permits. In moving around in the water they stay clear of one another and won't bump together They don't like each other, so to speak

As long as the clay particles remain separate, the lifting power of water on them is greater than the pull of gravity. They remain in suspension, and the water stays muddy.

Lime (or, chemically speaking, Ca) has a positive or plus charge. Lime molecules or particles repel each other, also, because they have like charges. But when we put lime in the muddy clay water, we create a new condition.

We put Ca, which has a positive or plus charge in with clay, which has a negative or minus charge. The plus charge of the Ca attracts the minus charge of the clay. The Ca and clay particles draw together about like a magnet draws steel. They join hands so to speak. Or, even better, they hug or embrace—become closely associated.

When the Ca and clay particles unite, they do something else to the water. The union of the plus charge of the Ca with the minus

charge of the clay neutralize each other—cancel each other out. There are no repelling or attracting forces left, so there is nothing left to repel or attract the united particles of Ca and clay. All these forces are neutralized—wiped out.

From this point on, the particles formed when the Ca embraces the clay have no charge. They neither repel nor attract other particles, and the movement is different from what it was in the muddy clay water. These new particles move like people blindfolded. Because they can't see where they are going, they begin bumping into each other when they are put in a small room or close space. Each time they do, they linger a while. They don't rush away. Soon several of them collide at the same time and place to form little groups or loose clusters.

As the number of clay particles in one of these clusters increases, so does their combined weight. Soon, sufficient clay particles join the cluster to make it weigh enough for the pull of gravity to overcome the lifting force of the water At this point the clusters settle out, and the water clears up.

This is the first step in forming a soil aggregate. We call this "flocculation," because each of these clusters is called a floc. Hence, we have a flocculation, which is the formation of flocs or loose clusters. One portion of the sugar has a positive or plus charge and acts like Ca. It flocculates the clay to form floccules, or loose clusters.

The object of flocculation is to pull the clay particles close enough together to be cemented with gum, which is made from sugar. The individual molecule—or unit—of the gum is short so doesn't reach very far. It can't bridge the space between clay particles unless they are pulled together. Unless the clay particles are pulled close together—grouped in loose clusters—the molecules of gum can't stick on but one particle. It can't reach a second particle to bind or cement them into clusters or aggregates.

The second or next step in aggregate formation is the binding of the clay particles in the flocs into crumbs or aggregates. Nature binds these loose clusters of soil grains firmly into aggregates by use of another portion of the sugar that is negatively charged. This is done in much the same way popcorn is held together in balls by sugar or syrup. You cook the sugar or syrup until it becomes sticky, like gum. Then you pour this gum-like material over popcorn kernels arranged in clusters in order to bind them into balls.

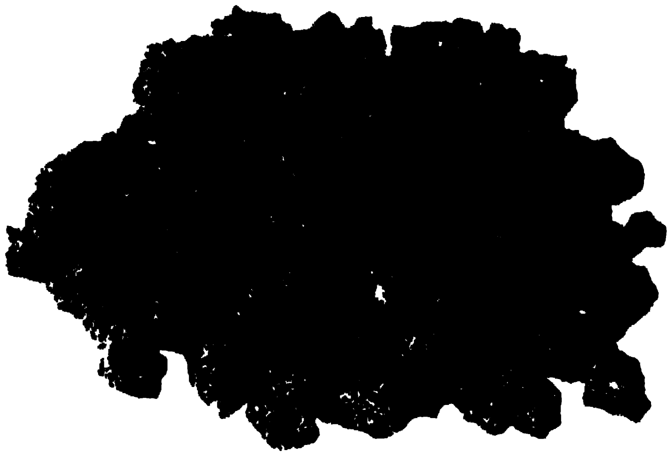


Figure 5-4. This sample of virgin soil was put in a bottle of water, shaken fifty times, dumped on paper, and dried. The aggregates remained intact It has a well-developed granular structure. (Soil Conservation Service Photo)

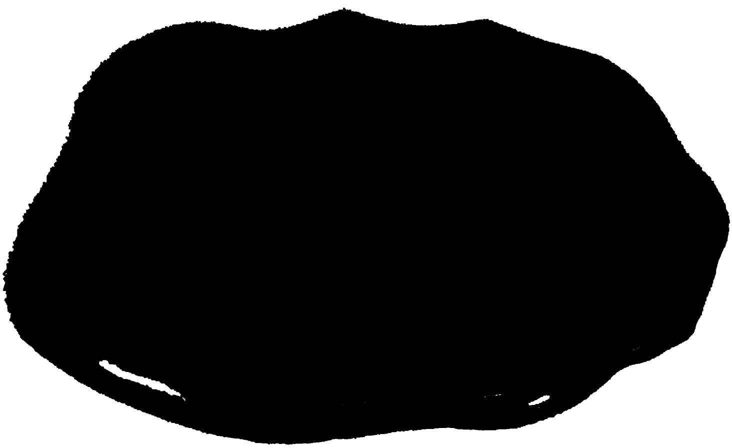


Figure 5-5. This sample of soil came from a cornfield just across the fence from the sample in Figure 5-4. The cornfield had been row cropped for a number of years. It was treated the same as the sample in Figure 5-4, but it was compacted and the aggregate structure has been destroyed. (Soil Conservation Service Photo)

Nature's method of getting sugar into the soil crumbs is not as simple as your method of getting syrup or sugar into popcorn balls. You start with sugar or syrup; Nature starts with dead plant parts on top of the ground, which are changed into sugar.

You pour the gum-like sugar or syrup directly on the popcorn; Nature works the raw plant material into the ground around the soil grains first. They are dissolved in the water that surrounds each soil particle, then these are made into sugar by soil microbes. They are made into sugar directly on the surface of the soil grains.

Nature uses rainwater and melted snow to get the dead plant material into the ground and around the soil grains. Some of the plant material is carried into the ground every time water passes over it. The water dissolves out part of it, just as hot water dissolves substance out of coffee when poured over ground coffee. The substance that makes the water brown is what microbes use in making sugar.

The gum-like material used in cementing flocs into crumbs or aggregates acts like bridges. It holds the soil grains together, yet it keeps them apart. It won't let them pack down tight.

You can illustrate this with BB shot and soft tar. Stir the shot in the tar. The tar will hold the shot together, yet it will keep them apart. They won't touch each other, because there is a film of tar between them so they can't pack down tightly.

REMOVAL OF PLANT COVER DESTROYS AGGREGATION

Sugars that bind soil grains into aggregates must be replaced frequently, because other microbes use them as food. Nature solves this by keeping the ground surface covered with dead plant material. Every time it rains, or snow melts, a new supply of soluble plant material is carried into the ground for the production of more sugar.

Removing the plant cover interrupts this process. When the sugar binding the soil grains into aggregates is destroyed, the aggregates break down—fall apart.

The longer the soil is without a protective plant cover, the more complete the breakdown of aggregation. But, renewing plant cover

stops the breakdown process and starts building back the aggregates.

Plant cover can be maintained by planting grasses and clover or the addition of straw and other dead plant material as mulch. Another method is to leave plant trash on top of the ground instead of turning it under. Plant trash left this way supplies the soluble material to make the sugar. Restoring plant trash starts the formation of aggregates, building back good structure.

Accumulation of plant residue on the surface of the ground is Nature's way of providing the soil with a steady supply of sugars for aggregation. These supplies are constantly being added to with material in the form of falling leaves, twigs, and other above-ground parts of plants.

LEAVE PLANT COVER ON THE GROUND

Plowing under plant residue causes all the soluble material to be made quickly into sugar. This leaves no new supplies to replace

Figure 5-6. Soil splash is impossible beneath a cover like this cushion of little bluestem grass and oak leaves on an excellent-condition range in the Cross Timbers of Texas. This condition maintains good soil structure. (Soil Conservation Service Photo)

sugars broken down and produces a high state of aggregation for a short time. After the original supply of sugar is destroyed aggregation breaks down. Plowing hastens the rate at which soil crumbs are destroyed.

This shows it is better to leave plant trash on top of the ground. When left there, sugar binding soil grains into aggregates can be replaced frequently.

AMOUNT AND QUALITY OF ORGANIC MATTER IMPORTANT

Both the amount and quality of organic matter affect the formation of aggregates. The amount determines the quantity of soluble material carried into the soil each time it rains. It also determines how long these substances can be supplied.

The quality of the organic matter determines the amount of sugar produced from the organic matter, or the amount of material available for binding soil grains into crumbs.

Large amounts of organic matter, as in continuous grass, produce lots of aggregates. On the other hand, small amounts or no organic matter, produce few or no aggregates at all.

The plant parts that produce aggregates serve as food for soil microbes. These microbes keep the soil healthy, decompose the organic matter, and make plant food available. They also destroy harmful organisms, help keep down plant diseases.

CROPPING SYSTEMS INFLUENCE AGGREGATION

Cropping practices that leave large amounts of trash on top of the ground aid soil aggregation. Soils limed and planted to clover have more aggregates than similar soils planted to clover without liming. They produce more clover, have more trash, and produce more sugar. Cropping systems that provide continuous plant cover favor total aggregation. Soils well fertilized produce lots of plant growth. They become more highly aggregated where the trash is left on top of the ground.

Practices that produce lots of aggregates also produce high crop yields. The best way to increase crop yields is to aim at a high degree of soil aggregation. Cropping systems that keep the ground covered with growing plants or plant trash favor formation of lots of aggregates, which make a soil productive.

CULTIVATION DESTROYS SOIL AGGREGATION

No one has succeeded in improving on Nature's way of building and managing soil. Nature keeps the surface of the ground covered with a blanket of plants to protect the soil from the harmful effects of wind and water. The soil retains the mineral plant food made available from rock during the soil-building process. The soil also accumulates organic matter from the plants forming this cover.

The result is usually a topsoil well supplied with organic matter. It becomes a soil that is in good tilth, well aggregated and aerated, and one that absorbs water freely and has lots of room for storing water for plant use.

When we took over, we upset Nature's smoothly operating program and destroyed the blanket of plant cover. We either burned it off or plowed it under. By destroying this plant cover, we introduced two harmful practices. We removed the protective plant cover and disturbed the soil by plowing it. Both practices were opposed to the program developed by Nature.

We abruptly stopped Nature's soil-building process by destroying the plant cover. This also robbed Nature of her means of holding the soil in place. We exposed the bare soil to the action of wind and water, so much of the plant food and dead plant material was lost.

Frequent plowing and cultivation made the situation worse. Each plowing brought new soil to the surface, and this constant stirring hastened the final destruction of the crumb structure. It also increased erosion. With each plowing or stirring the soil became more compact. It absorbed less water, so its water storage capacity was reduced and less water was stored in the soil for plant use.

AGGREGATES INCREASE PRODUCTIVITY

The aggregate condition is a fairly accurate index of soil productivity. In Iowa, land planted continuously to corn for thirteen years produced an average of 31.8 bushels per acre. Corn grown in a three-year rotation averaged 54.0 bushels. This was an increase of over 22 bushels per acre for the rotation.

The soil on the rotated plots was more highly aggregated than that on the continuous corn plots. Moreover, the difference in yield between the two treatments is rapidly increasing. In the last five years the corn grown in the rotation averaged 71.2 bushels per acre. Land continuously in corn averaged 23.9.

Exercises

1. Get a spade full of soil from either a forested area, pasture, or meadow and another from a cultivated field. Spread out on a smooth surface and compare the two samples. The sample from the forested area, pasture, or meadow will be loose and friable, full of small crumbs. The one from the cultivated field will be compact, and the clods will be hard and lumpy. Why this difference?

2. Place a small handful of each of these two samples in a jar of water and shake a few times. Pour out on paper and let dry. Notice that one sample will retain its crumb-like structure. The other will look like a mud pie. Why this difference?

3. Locate a spot that has been covered with trash mulch for several weeks or months. Take a sample of soil from beneath the mulch and compare with one from a bare spot near by. Make the same tests as in No. 1 above. The sample from beneath the mulch will compare with the one from the forested area, pasture or meadow. The one from the bare spot will compare with the one from the cultivated field. Why?

4. Select an area in the garden or in the flower bed and cover about three to four inches deep with straw, leaves, or other trash. Add new material every two or three months. At the end of about nine months or a year examine the soil beneath the mulch. The layer at the immediate surface will be darker than that below. The soil mass for a short depth will be better granulated than at the time the project was started. Soluble portions of the mulch cover have been leached and carried into the ground where the microorganisms continued the decomposition process, which started in the lower areas of the mulch layer. The products produced by the microorganisms supplied the cements to form the aggregates.

Questions

1. What are the main differences between soil from a forest or pasture and cultivated land? What makes these differences?
2. What makes wood and pasture soils soft and springy? What are the crumbs or little clods that make it that way? How do they affect the productivity of the soil?
3. What is soil structure? What makes a good soil structure?
4. Sometimes soils well supplied with plant food do not produce big yields. What is the relation of less yields to soil structure?
5. Why is it necessary that we know how soil crumbs or aggregates are formed? What happens when lime is put in muddy clay water?
6. What binds soil grains into granules? How are these gums produced?

7. What is flocculation? How does it work? What is its importance in crumb formation?
8. Explain the different steps nature uses in producing gum or sugar to cement soil grains together
9. Why is it necessary to have the ground covered with dead plant material? How does Nature keep the ground covered with plant trash?
10. Why is both amount and kind of organic matter important in crumb formation?
11. How does plowing affect soil aggregation or tilth?

6

Soil Surveys

THE soil survey is an inventory of the soil—a record of the physical land features. It is a listing of the land features important in determining how the land can be used best. These features, recorded on a map or aerial photograph, include the kind of soil, steepness of slope, type and degree of soil erosion, and overflow or salinity problems. The survey shows the land features in enough detail to furnish information to plan its use. Soil surveys are used in planning soil and crop management programs on the farm.

LAND-CAPABILITY CLASSES

The Soil Conservation Service used the information on physical land features to group soils on a more useful basis. As a result, the soils of the nation were grouped into land-capability classes. Land-capability classification groups soils on the basis of their susceptibility to erosion under agricultural use. It shows the limitations on use of various soils. The soil survey shows the limitations of use of the various soils on the farm. It serves as a basis for planning correct land use.

Land-capability classes, being summarizations, for farm use, of the soil information show how climate, slope, and erosion affects use of the soil. They also show how overflow and salinity problems restrict its use. To make it easier to use, the capability of each kind of land is shown in a different color.

The land-capability maps are used by farm conservation planning specialists to serve as guides in developing sound plans. They are

a guide to the proper use and protection of all the land on each farm. Soil surveys also serve a broader use. They serve as a source of information in planning for immediate and long-time operations over large land areas.

SOIL MAPPING UNITS

The smallest division of soils in this classification is known as a mapping unit. Mapping units contain soils alike in those characteristics known to be important in farm planning. The characteristics are indicated by symbols (signs) on the soil survey map. Some of these characteristics can be seen directly, others may have to be determined from the information given.

Ordinarily the most important soil characteristics are effective depth, texture of surface soil, and permeability of subsoil. Thickness of soil or subsoil layers, permeability of the underlying material, moisture-storage capacity, internal drainage, degree of acidity or alkalinity, amount of organic matter, or amount of plant nutrients are also used.

Effective depth of soil. Effective depth of soil is the depth plant roots penetrate readily in search of water and plant nutrients. It is the depth or layer of soil most favorable for growth of roots and for the storage of moisture for plants. Effective depth may be limited by underlying material. Some underlying materials interfere with normal root development.

A shallow soil has limited amounts of plant nutrients and small water storage capacity. Generally speaking, crops suffer from lack of water more quickly on shallow than on deep soil. Land leveling for irrigation may be impractical on shallow soil. The gradients of terraces may depend on the effective depth of soil. Other soil management programs are affected by the effective soil depth.

The following descriptive terms and ranges are used to define effective depth of the root zone:

Deep	36 inches or more
Moderately deep	20 to 36 inches
Shallow	10 to 20 inches
Very shallow	Less than 10 inches

In some localities soils need to be arranged in two groups on the basis of effective depth. One group includes soils without layers limiting root growth at any depth, or at some depth below 60 inches.

The other group includes soils with restricting layers at depths of 36 to 60 inches. The term "very deep" could be used for the first, and "deep" for the second.

In some areas, information about layers within the effective depth of soil may be needed. These include thickness of the surface soil,

Figures 6-1 & 6-2 Profiles of a Miami silt loam from a wooded area and from a cultivated field in Iowa. The profile from the wooded area shows the A, B, C, and D horizons. All of the A horizon and a portion of the B horizon have been removed by erosion from the cultivated field. The A and B horizons are subdivided. (Soil Conservation Service Photo)

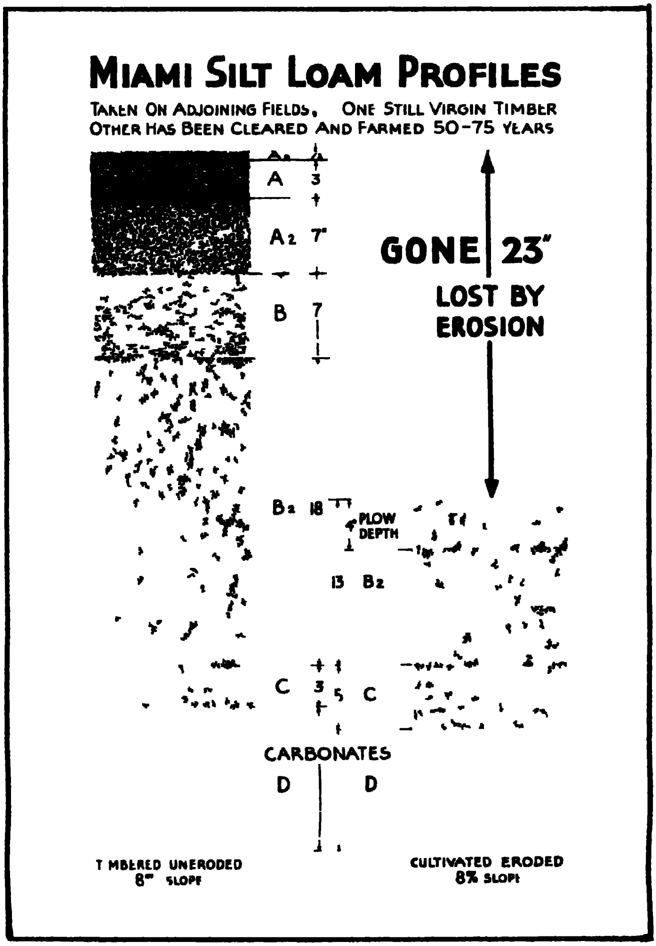


Figure 6-3. Removal of plant cover destroys soil crumbs (tilth). The soil in these two views is the same type. That on the left remained in grass, while that on the right came from a cornfield just 25 feet away.
(Soil Conservation Service Photo)

thickness of subsoil, and thickness of sandy soil over a layer of much lower permeability. The following terms fit most conditions:

Thin	0 to 6 inches
Moderately thick	6 to 12 inches
Thick	12 to 18 inches
Very thick	18 to 36 inches

The terms "thick" and "thin," with appropriate prefixes, are used in describing soil layers other than effective depth. "Deep" and "shallow" are used in expressing effective depth. For example, it is thin surface soil, not shallow surface soil.

Texture of surface soil. Texture[1] of surface soil is closely associated with workability, permeability, and other soil characteristics. The fifteen or more textural classes are placed in seven or less textural groups for farm planning.

Permeability. Permeability of a soil is its capacity to transmit water or air. It is the rate water flows through soil.

In mapping, the permeability of each horizon (See Figure 6-1.) within the effective depth of soil is determined. In most instances, permeability of the layer limiting effective depth is also determined. Permeability of all soil horizons and their relation to each other and to the entire profile is considered. Often, the chief concern is with the one or two least permeable horizons.

Permeability of the surface layer affects the infiltration rate of water into the soil. Actually, the permeability of the top one or

[1] Texture refers to size of individual soil grains.

two inches of soil fixes the infiltration rate. The highest rate is attained under ideal cover and soil structure conditions. Infiltration rate is not considered in setting up soil-mapping units. It varies too much. It usually can be inferred from the mappable soil characteristics. This is especially true when the cover and surface conditions are known.

The seven degrees commonly used to express permeability of agricultural land are:

Rate of Permeability	*Percolation in Inches per Hour*
Very slow	Less than .05
Slow	0.05 to 0.20
Moderately slow	0.20 to 0.80
Moderate	0.80 to 2.50
Moderately rapid	2.50 to 5.00
Rapid	5.00 to 10.00
Very rapid	More than 10.00

Fewer or more divisions may be used as conditions require. If, for example, three divisions should prove to be enough, the descriptions "slow," "moderate," and "rapid" would be sufficient. Permeability, or rate of percolation, should be given where possible.

Available moisture capacity. Available moisture capacity is a soil's ability to store water for plant growth. Total available moisture capacity is the sum of the capacity of different layers in effec-

Figure 6-4. Grass sod means good soil tilth. Grass litter provides a source of sugar for soil crumb formation. This native Texas grassland has lots of crumbs and good tilth. (Soil Conservation Service Photo)

tive depth. This capacity determines a soil's ability to supply moisture during droughty periods.

The following terms and ranges are used for five degrees of available moisture capacity:

Degree of Availability of Moisture Capacity	*Available Moisture capacity in Inches of Water per 60 Inches of Soil Depth*
Very high	12 inches or more
High	9 to 12 inches
Moderately high	6 to 9 inches
Low	3 to 6 inches
Very low	Less than 3 inches

Texture and organic matter content are factors influencing available moisture capacity. Silt loams, for example, hold more available water per foot than sandy loams. Loamy sands hold less than fine sandy loams.

Reaction. Degree of acidity or alkalinity (*p*H range) is occasionally of use in separating soil mapping units. This is especially true for determining the need for lime and sulphur. The following *p*H ranges are used:

Acid	Less than *p*H 6.5
Neutral	*p*H 6.6 to 7.3
Alkali	*p*H 7.4 or more

Natural soil drainage. Mottling, especially mixtures of grayish, pale yellow, yellowish, and rust-brown in the soil profile indicate

Figure 6-5. By using crop residue as a mulch we can have good crumb-like structure in our cultivated fields too. The cornstalks on this South Carolina field should have been cut into lengths short enough to work through. (Soil Conservation Service Photo)

poor aeration. These soil colors indicate poor drainage or lack of air. Brighter yellowish or reddish colors indicate good aeration and drainage. The following profile drainage characteristics are used.

Well-drained. Soil is well oxidized—iron broken down—and free from mottling. The underlying material may be slightly mottled or splotched.

Moderately well-drained. Soil is well oxidized. It is free from mottling in the topsoil and upper part of the subsoil. Slight mottling of grayish and rust-brown colors may occur in the lower part of the subsoil.

Imperfectly drained. Soil is well oxidized. It is free from mottling in the surface. The subsoil is mottled with grayish, yellowish-brown, and rust-brown colors. The degree of mottling is usually greater than in the lower part of the subsoil of moderately well-drained soils.

Poorly drained. Soil is mottled grayish brown and brownish. It may be gray at or near the surface. It often has light grayish layers just above the subsoil. The mottling is usually highly contrasted. Yellowish, grayish, and rust-brown colors predominate. Small iron-like particles may occur on the surface

Very poorly drained. This is soil with a dark-colored surface layer It has gray or grayish and rust-brown subsoil. It usually occurs on flat or slightly depressed areas—areas where water stands, or formerly stood, for long periods. Also included are soils developed in places covered by water. Peat and muck occur in such places, but the conditions have favored the accumulation of plant remains.

Natural fertility. Natural fertility is an important factor in selecting soil-mapping units. The degree of fertility often determines the use, management, and amount of protection needed. Such characteristics may be mapped within helpful limits.

Natural fertility is the amount of plant nutrients present. It is difficult to determine on any national scale. This factor should be used only to separate mapping units alike in other characteristics. Usually four degrees of natural fertility are enough. They are: high, moderate, low and very low.

Organic matter content. The organic matter content of a soil indicates its durability and productive capacity. Often it can be determined on the basis of observable characteristics, such as color and sponginess of the soil. Organic matter needs can be determined by soil's tendency to crust or "bake." Organic matter content should

be used only to separate mapping units otherwise similar. The following broad classes are usually sufficient: high, medium, and low.

Underlying parent material. Parent material is the substance soil came from. It often is an important factor in setting up units for soil surveys. Soils developed on limestone by glaciers may be more desirable for some crops than those developed on acid glacial material. Limestone soils usually are more productive than those derived from nonlimestone material. The latter contains sandstones, acid shales, and granitic rocks. Parent material may indicate soil deficiencies. These deficiencies may be lack of copper or manganese, or the presence of such toxic elements as selenium.

Organic soils. Organic soils are made up of dead plants, which are called peats and mucks. Properties of these soils used in setting up mapping units are: (1) thickness of organic materials, (2) kind and thickness of underlying material, especially its permeability; (3) reaction (*p*H range); (4) texture or structure of the surface layer, whether it is peat or muck; (5) *character or composition of* organic material, such as sphagnum peat and sawgrass peat.

The term "shallow" should not be used unless the characteristics of the profile add up to the equivalent of a shallow soil. For example, *eighteen inches of peat over sandy clay may have the crop-response* value of a deep soil. On the other hand, eighteen inches of peat over limestone may be described as shallow.

Names and descriptive titles for soil units. Suitable names or descriptive titles should be given each soil unit. Important soil types occurring in each mapping unit should be listed, if available.

ASSOCIATED LAND FEATURES

Associated land features are important in farm plans. These include slope, erosion, wetness, salinity, overflow hazard, and susceptibility to stream-bank cutting.

Slope. Steepness of slope affects velocity of runoff rate of erosion, use of farm machinery, and land management practices.

Important ranges or classes of slope are determined. If the soils, climate, and important land-use factors are fairly uniform, one group of slope classes may be enough In some areas, two or possibly three groups may be needed. For example, one group of slope classes might apply to moderately and rapidly permeable soils. Another may apply to slowly permeable and claypan soils.

These terms are suggested for designating different slope classes: nearly level, gently sloping, moderately sloping, strongly sloping, steep, and very steep.

Erosion. Erosion is the movement of soil by natural agencies—usually wind, water, and slides. Geologic erosion is normal, not a result of human activity. Mapping in soil surveys for farm planning is concerned with man-made erosion.

Soil erosion mapping shows three things: (1) changes that have occurred, (2) the rate of past and possible future damage, and (3) what is left in the way of productive topsoil.

Degree of wetness in some instances can be classified and mapped. Resulting from a number of factors, it may be due to high water table, suspended water table, seepage, slow escape of water from level areas, or slow drainage of heavy soils. These conditions leave their imprint on the soil profile or in the kind of vegetation present.

Degree of wetness cannot be used as an indicator of permeability. A soil may be wet, regardless of its permeability. If it contains ground water held by a deeper slowly permeable or impermeable layer or barrier, it will be wet. Both degree of wetness and permeability are important to land utilization.

Experience indicates that four degrees of wetness will meet most farm planning needs. These are:

Slightly wet:	Growth of crops may be slightly affected or the planting dates delayed for brief periods.
Moderately wet:	Growth of crops may be moderately affected or planting dates delayed by a week or so.
Very wet:	Growth of crops seriously affected, or planting delayed as much as a month or more; may be usable for improved pasture.
Extremely wet:	A swamp or marsh too wet for cultivated crops or improved pasture. Usable only for wildlife and certain trees.

Salinity. Presence of salts in amounts toxic to commercial plants frequently limits land use. At least three classes are needed in irrigated areas. The following usually are sufficient.

Slight salinity:	Crop yields are slightly affected, or the range in adaptable crops is slightly limited.
Moderate salinity:	Crop yields are moderately affected, or the range in adaptable crops is moderately limited.

Severe salinity:	Crop yields are seriously affected, or the range in adaptable crops is severely limited.
Very severe salinity:	Satisfactory growth of useful vegetation is impossible except, possibly, of some of the most salt-tolerant forms.

Frequency of overflow. Overflow hazards often influence the use and management of land. For adequate land-capability classification, the frequency and duration of expected overflows is important. Specific standards for the separation must be established to fit local needs. Below are listed three broad standards that meet most common needs:

Occasional overflows or overflows of short duration	Crops occasionally damaged or planting dates somewhat delayed.
Frequent damaging overflows or overflows of long duration	Crops frequently damaged or range of adaptable crops limited.
Very frequent damaging overflows or overflows of very long duration	Not feasible for growing cultivated crops.

These classes may need to be defined more precisely to cover local conditions. The time of flooding may also be indicated.

Other factors. Bottom lands subject to stream-bank cutting may need to be indicated and identified. Occasionally, the topographic position has enough significance to warrant separate expression. Character of the substratum usually can be covered in the soil mapping units.

MAPPING PRESENT LAND USE

Information on present land use (or land cover in the case of land not used for crops) is needed for farm planning. It is important to know the location of the following classes of land: cropland (L); idle land (X); pasture or grazing land, or grassland (P); woodland (F); and possibly brushland. Others may be set up if needed, but each should be clearly defined.

EXERCISES

1. Walk over the cultivated portion of your home farm or that of a neighbor or a friend. Record in a rough sketch the most important

types of soil you observe. Show the location and approximate extent of each. (If you have access to a soil map of the farm, all the better.) Show in this same sketch where the various crops are grown. See what relation you can find between the main characteristics of the different soils and the particular crops on them.

2. Examine the soil profile as shown by the banks of ditches or gullies. Draw a sketch showing the different layers (horizons) of the soil. Take quart samples of soil from each layer of soil to the laboratory. Place equal amounts of the various samples in funnels, which have been lined with filter paper, and pour water over them. Notice the difference in the rate the water moves through the samples.

Questions

1. What is a soil survey? How is it made? What does it include? What is it used for?
2. What is a land-capability class? How is it made?
3. What is a soil mapping unit? What does it contain?
4. What important soil characteristics are used in making up mapping units?
5. What is meant by effective depth of soil?
6. What is the difference between effective depth and thickness of surface soil?
7. Define soil texture. Soil permeability.
8. What fixes the infiltration rate of soil?
9. What determines total available moisture capacity of a soil?

7

Land-Capability Classes

THE soil is the basis for all cropping programs. If used wisely, it can be made to produce high crop yields indefinitely and be improved at the same time. But if it is unwisely used or used for purposes for which it is not suited, the results will be disappointing, even disastrous. It is important that the farmer know the capabilities of his soil. It is as important that he know the capability of his soil as that of his machinery or of each type or class of livestock.

It is unwise to use sandy soil to produce crops that require heavier types of soil. Neither is it wise to select steep hillsides to grow clean, cultivated row crops. Sandy soils produce their highest yields when planted to crops best suited to them. They produce most when they are managed in a way best suited to their needs. Likewise, heavier soils respond most favorably to crops adapted to them and produce largest crop yields when given proper management. Management should insure against erosion and other forms of deterioration. It would not be wise to plant steep hillsides to clean cultivated crops, when at the same time bottomlands are planted to trees and grass.

Those soil and crop management practices that give the best crop yields over a period of years also provide the best protection against soil erosion. Otherwise, it would not be possible to continue growing crops year after year on a field without the yield declining. It would eventually decline to such an extent that planting it to crops would no longer be profitable.

It was pointed out in an earlier chapter that soil erosion is a destroyer of soil. Erosion is the greatest single factor responsible for

the destruction of farm land It will be shown in a later chapter that soil erosion lowered crop yields about as fast as improved methods of farming increased them. The result was a stand off in crop yields. Erosion neutralized the benefits of soil and crop management In short, soil erosion may be compared to a bunghole in a barrel As long as the bunghole is open, the barrel cannot be kept filled with water The water runs out at the bunghole as it is poured in the top, if the bunghole is stopped, the barrel can be kept full

We now know how to stop this bunghole that has leaked so much of our soil fertility The first step is to make a study of the soil in each field on the farm We need to find out its peculiar characteristics and learn how each soil type differs from the other, how these differences affect the use of the soil, and how they affect crop and soil management needs

This approach looks upon the soil as being a living thing—something that can be made to grow when properly managed Or it can

Figure 7-1 The soil man bores with an auger on this Maryland farm to find out the kind of topsoil and subsoil The information obtained is recorded on an aerial photograph of the farm (Soil Conservation Service Photo)

Figure 7-2. The soil surveyor uses an adjustable level to measure steepness of slope in this Wisconsin field. (Soil Conservation Service Photo)

be destroyed when improperly managed Soil is something that will increase in value and productiveness when put to proper use and correctly managed.

The key to proper use and management of soil, then, is an intimate understanding of the land This includes knowledge of the various soil types on the farm and of their characteristics, possibilities, limitations, and needs.

All farmers know a good deal about some of the different kinds of soil they are farming They do not know the good and bad points about all their soil, though – that is, each type of soil Stream bottomlands, for example, are easy to recognize Some are sandy, others are moderately sandy or loamy, and some are heavy (clayey). There are well-drained ones and naturally wet kinds Some of the uplands are moderately sloping, steep, or nearly level. Some soils take in water readily, others do not. A number of farmers know something about many variations of land.

There is an amount of the level land that is good for cultivation, but some of it may be too wet Two or three different types of soil

may occur on similar locations, such as nearly level land, gentle slopes, moderate slopes, and on slopes so steep they cannot be safely cultivated. Often there are four or five different types of soil on a single farm. There may be more, if the soil is unusually variable.

To determine the best use for each type of soil on a farm takes time and study. To select the best practices for each kind takes more study and time.

Let's consider the job of finding out about land. We want to find what it will do best and to know what management and treatment it needs. A soil inventory helps a farmer know the kinds of land he has, so methods have been developed for making such an inventory.

The soils specialist is usually the first to visit a farm, perhaps even before the farmer applies for help. The soils man supplies the farm planner with information when he visits. The soils man uses an auger or sometimes a spade, to sample the soil. He bores or digs deep enough to find what is beneath the surface, so that he may know all

Figure 7-3. This Hagerstown silt loam in Pennsylvania has seven inches of dark-colored topsoil in the A_1 horizon. This is underlain with the A_2 horizon, which consists of about five inches of grayish-brown, granular, friable silt loam. Immediately below this is about a twelve-inch layer of loam, which is mottled yellow and red, moderately compact, somewhat plastic when wet, hard when dry, cloddy and silty. This loam makes up the B horizon, which rests on limestone bedrock. (Soil Conservation Service Photo)

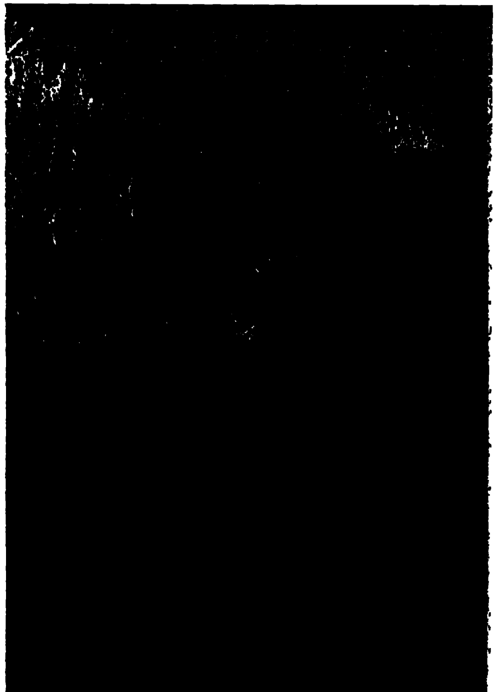


Figure 7-4. Kirkland silty clay loam in Oklahoma. This soil was developed under grass. It is dark in color and loose and friable to a depth of from three to four feet. It absorbs water readily. (Soil Conservation Service Photo)

he can about it. He doesn't map soil just on the surface alone but looks under the surface. He wants to know what the subsoil is like, too.

You can't tell what is inside of a book by just looking at the cover. You must open it—read it. You can't just look at the topsoil and tell the kind of soil. You must look inside, examine the layers, and interpret what you find. Even those farmers who know their soils find the soils man helpful. He can usually explain things they have seen for years but did not understand.

The soils man also carries a small adjustable hand level, which he uses to measure the steepness of slopes. He carries a map on which to write down what he finds out about both the soil and its slope. This base map is an aerial photograph that shows roads, buildings, streams, and other features. Usually the individual field can be recognized. The soils man maps erosion condition, as well as outstanding poor drainage and excessive salt content.

The soil-capability map has for the farmer useful information about his land. It shows idle lands, gullies, and the like. He can keep the map in a handy place with his other records and refer to it from time to time. Colors on the map tell him the suitability of his soil for

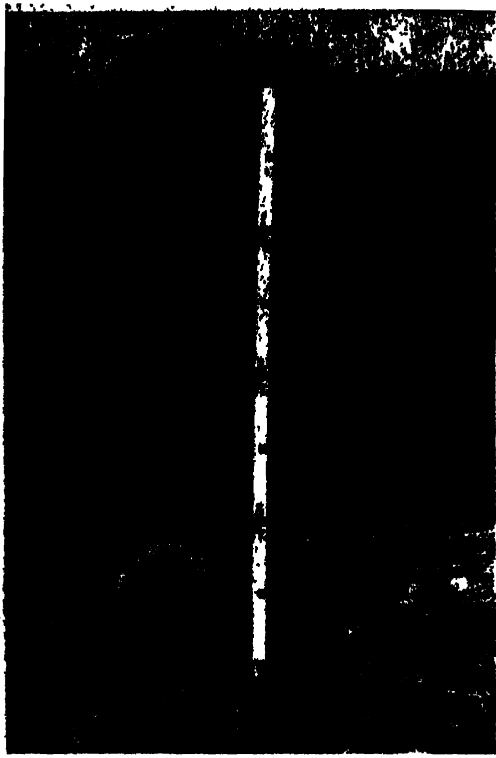


Figure 7-5. Vernon fine sandy loam in Oklahoma. The zero- to twelve- or fourteen-inch layer represents the A horizon. It is brownish to grayish-brown fine sandy loam. The B horizon, from a depth of twelve-fourteen inches to about thirty inches, is reddish-brown to red sandy clay. Between this and the parent material (thinly laminated sandstone shale) is the C horizon. (Soil Conservation Service Photo)

cultivation and for other uses. This chapter explains what the colors and symbols shown on the map mean. Brief descriptions that go with the map tell something about each kind of land: texture and depth of soil, steepness of slope, and erosion. They also tell about suitable cropping practices and show the principal practices needed for erosion control, water control, and other special management features.

The soil-capability inventory gives only a part of the information needed in making a farm plan. The completed map shows where strip-cropping, contour farming, terraces, diversions, or other practices are needed.

FACTS OBTAINED IN THE FIELD

A careful examination of the soil in the field is necessary, because this is the only way to determine the capability of the soil. The capability map gives the farmer additional information about his soil. The soils man walks over the ground, bores holes in the soil, and determines its depth. He determines texture, permeability, available moisture capacity, inherent fertility, organic matter content,

and other characteristics that affect the use, management, and treatment of the land. He measures the slope, determines the soil loss by erosion, and the overflow hazards. He also determines the wetness of the land and other significant characteristics. He notes the present use of the soil, and these facts are recorded on the base map to be used later in making the farm plan.

SIGNIFICANT VARIATIONS IN SOIL CHARACTERISTICS

Mapping units have wide enough differences to require different soil management practices. They have different uses, crop yields, and management requirements. Each soil characteristic is considered in relation to all others in determining what the land can do.

SOIL IS CLASSIFIED

With these facts, the soil can be classified according to its capability—its ability to produce permanently under specified uses and treatments.

Agricultural specialists and local farmers work together deciding how the land should be used. They determine the practices needed for each kind of land. Physical land conditions, research findings, and technical information are combined with farm experience. This combination serves as a basis for classifying the soil to get the right combination of practices for the land. These practices enable the farmer to make full use of the land and improve it, too.

The system of land classification helps organize significant soil facts for farm use. It is known as the "soil-capability classification." The term "capability" relates to the degree of hazards and limitations in managing the land and also shows the land's best use.

The soil factors, determined in the field, serve as a basis for judging soil capabilities. These characteristics are also used in determining the best use of the various soil classes. They show soil and crop practices that protect the soil from the forces of erosion, thus insuring top crop yields.

THE CLASSIFICATION SCHEME

A map is made of each farm to show soil types, slope, and other important physical land characteristics. Soil units are grouped into

Figure 7-6. Soil-capability classes show how much difficulty or risk is involved in using land. Class I land is level and easy to farm, being subject only to fertility and puddle erosion. Classes II and III contain the soil suited for cultivation but limited by slope, sandy soil, tight subsoil, or some other feature. Class IV soil requires care if cultivated. Soil in Classes V, VI, and VII is suited for grazing or for forestry. The higher the class number, the greater the permanent limitations of the land. Class VIII soil is not suited for cultivation, grazing or forestry. (Soil Conservation Service Photo)

capability units, which are units that require different cropping systems and soil treatment. This insures continued use of the land at the highest production level the land is capable of supporting.

Each capability unit consists of a group of soils with specified limits. These limits include soil type, slope, degree of erosion, and other physical characteristics. All the soils in a capability unit are about equally susceptible to wind or water erosion under the same kind of plant cover. Similar cropping systems or other management practices are applicable throughout the unit. The capability units are the physical land-treatment units, as far as permanent soil factors are concerned. Each one, consisting of one or more mapping units, has nearly uniform use possibilities and conservation needs.

The capability units are grouped in successively broader divisions,

known as subclasses and classes, where such groupings are useful. Those units making up a capability subclass have about the same kind and degree of permanent limitations. These subclasses are then grouped into eight capability classes according to the degree of permanent limitations. The eight capability classes are finally grouped into two divisions: soils suited for cultivation and those not suited.

SUITABILITY FOR CULTIVATION

Cultivation is used broadly to include all that involves tillage of a soil. Land considered suitable for cultivation is workable. It is not too steep, not too wet, and not too severely limited by other factors. Limiting values of the different factors vary from place to place. The significant relation is that of the combined physical factors to safe, long-time use. In some places, for example, a slope of 10 per cent is too steep for cultivation, in other places, in a different environment, slopes of 10 per cent or more may be cultivated safely.

The degree to which the risks of damage limit the chances of safe, long-time use are important factors. They are used in grouping soils in a capability classification. The damage risks include erosion and other land damages, but shallow soil depth, tight subsoil, and stoniness are also considered. Most of the land not suited for cultivation is suited for, and will produce, some form of permanent vegetation.

EIGHT CAPABILITY CLASSES

Each of the two divisions, land suited and land not suited for cultivation, contains four capability classes. These eight classes are too general for the many specific recommendations about management and treatment of land. They are distinguished from each other by the degree of permanent limitations that is, risks involved in their use.

The subclass is the most convenient grouping for practical purposes. A capability class is determined by the *degree* of the total limitations on land use. But the subclass is determined by the *kind* of limitation.

For use on many small areas, such as a farm, the capability unit is the most convenient grouping. This allows the land operator to see the soil characteristics, which he already knows, but he can get

their meaning in terms of land limitations. Areas diverse enough to take in two or more kinds of limitations within one capability class often should be grouped into subclasses. The subclass is more useful in dealing with more diverse land conditions than those usually found on farms or small areas.

The capability classes differ from each other because of the permanent physical features. These limit land use or impose risks of erosion or other damages.

The classes range from I to VIII. Class I contains the land that has the widest range in adaptations. It can be farmed easily. The use of the land in the other classes is progressively more restricted because of permanent limitations.

SOIL SUITED FOR CULTIVATION

The soil in the first four capability classes is suited for cultivation.

Class I. Soils in Class I have no, or only slight, permanent limitations or risks of damage. They are very good, and can be cultivated safely with ordinary good farming methods. The soils are deep, productive, easily worked, and nearly level. They are not subject to overflow damage.

Class I soils used for crops need practices to maintain soil fertility and soil structure. These practices involve use of fertilizers and lime, cover and green-manure crops, crop residues, and crop rotations.

Class II. Class II consists of soils subject to moderate limitations in use and to moderate risk of damage. They are good soils that can be cultivated with easily applied practices.

Soils in Class II differ from soils in Class I in a number of ways. They differ mainly because they have gentle slopes, are subject to moderate erosion, and are of moderate depth. They are subject to occasional overflows, and are in need of drainage. Each of these factors requires special attention, because each restricts the use of the land. These soils may require special practices. Soil-conserving rotations, water control devices, or special tillage methods may be necessary. Frequently, a combination of practices is necessary.

Class III. Soils in Class III are subject to severe limitations in use for cropland and to severe risks or damage. They are moderately good soils that can be used regularly for crops—that is, provided they are planted to good rotations and given intensive treatment.

Soils in this class have moderately steep slopes, are subject to more severe erosion, and are inherently low in fertility.

Class III soil is more limited or subject to greater risks than Class II. These limitations often restrict the choice of crops or the timing of planting and tillage operations. They require cropping systems that produce adequate plant cover, which is needed to protect the soil from erosion and to preserve the soil structure. Hay or other sod crops should be grown, instead of cultivated row crops. A combination of practices is needed to farm the land safely.

Class IV. Class IV is composed of soils that have very severe permanent limitations or hazards if used for cropland. The soils are fairly good, and may be cultivated occasionally if handled carefully. Mostly, they should be kept in permanent hay or sod.

Soils in Class IV have unfavorable characteristics. They are frequently on steep slopes, subject to severe erosion, and are restricted in suitability for crop use. They should be kept in hay or pasture. A grain crop may be grown once in five or six years. In other cases, the soils may be shallow or only moderately deep, low in fertility, and on moderate slopes. They should be in hay or sod crops for long periods and planted to row crops only occasionally.

SOILS NOT SUITED FOR CULTIVATION

The soils in the last four classes are not suited for cultivation; they should be kept in permanent vegetation where possible.

Class V. Soils in Class V should be kept in permanent vegetation. They should be used for pasture or forestry. They have few or no permanent limitations and not more than slight hazards. Cultivation is not feasible, however, because of wetness, stoniness, or other limitations. The land is nearly level, and is subject to only slight erosion by wind or water if properly managed. Grazing should be regulated to keep from destroying the plant cover.

Class VI. Class VI soils should be used for grazing and forestry: They are subject to moderate permanent limitations. When in this use there may be moderate hazards involved. They are unsuited for cultivation. Because they are steep or shallow, grazing should not be permitted to destroy the plant cover.

Class VI land is capable of producing forage or woodland products when properly managed. If the plant cover has been destroyed, its use should be restricted until plant cover is re-established. As a

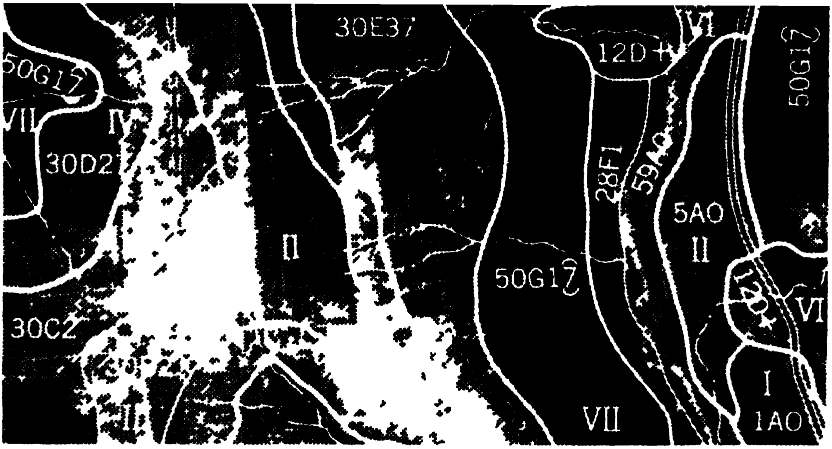


Figure 7 7 The large Roman numerals show the capability of each part of the farm Boundaries of the capability classes are outlined by heavy white lines The three part symbol made up of Arabic numerals and letters show soil, slope and degree of erosion (Soil Conservation Service Photo)

rule, Class VI land is either steeper or more subject to wind erosion than Class IV

Class VII Soils in Class VII land are subject to severe permanent limitations or hazards when used for grazing or forestry They are steep, eroded, rough, shallow, droughty, or swampy For grazing or forestry they are fair to poor, so they must be handled with care Where rainfall is ample Class VII land should be used for woodland In other areas, it should be used for grazing and strict management should be applied

Class VIII. Soils in Class VIII are rough even for woodland or grazing They should be used for wildlife, recreation, or watershed purposes

SOIL LIMITATIONS

The terms "very good," "good," "moderately good," and "fairly good" are used in soil-capability class descriptions They express the relative quality of land from the standpoint of all known physical causes, possibilities, and limitations These include slope, erosion, depth, and workability of the soil They do not necessarily express either present or highest productivity For example, a deep, dark-colored, fertile soil on a 10 per cent slope may have the same present productivity as a soil on a 3 per cent slope However, from the

standpoint of hazards of continued production, the former is classed as "moderately good" and the latter as "good." All soils in Classes I, II, and III must be at least productive enough to make regular cultivation for annual or short-lived crops practical.

CLASSIFICATIONS AND RECOMMENDATIONS

Within each area, land is described according to local conditions. Recommendations are also only local in scope. The program for each area is local in scope also. It includes best adapted crops, suitable practices, and best use for each kind of soil in each capability class.

Exercises

1. Select any hillside or a sloping area in a cultivated field. Take a spade and determine the approximate depth of the topsoil (the layer darkened by organic matter) near the top of the hill, about halfway down, and near the bottom. This layer of soil becomes thicker as you advance from the top to the bottom of the slope or hill. Why?

2. Make a sketch of a farm showing roughly the topography and the kinds of soils present. Use aerial photographs if available. Indicate the use to which you think each field is best suited. Compare this with a plan that has been prepared for the farm by the Soil Conservation Service, if such a plan is available.

3. Later in the season compare the growth and yields made by the crops growing on the same or similar areas as that suggested in No. 1 above. The yields, in all probability, will improve from the crest of the hill to the bottom. Why?

4. Indicate on the sketch made in No. 2 above the main soil-capability classes on the farm.

Questions

1. What is meant by soil capability? Why is it important?
2. Why is an intimate knowledge of the land so important? How is it obtained?
3. What is meant by soil inventory? How is it made?
4. What is the soil-capability map? What information does it contain?
5. Why is it necessary to examine soil in the field? What information is collected in the field?
6. What does the soil map of a farm show?
7. How was the soil-capability classification made up?
8. How many capability classes are there?

8

Soil Testing

RAPID chemical soil tests for determining lime and fertilizer needs are widely used. The need for soil testing has increased with the increased use of fertilizer. The purpose of soil testing is to determine the available supply of the major plant nutrients in soil. We have no sure way of measuring the available supply exactly, so laboratory tests have been developed.

Results of laboratory tests must compare favorably with the available supply of plant nutrients if they are to be of value. The accuracy of a particular soil test can be determined only by comparing its values with results obtained with field fertilizer experiments.

Soils vary widely in chemical nature. Consequently, a soil test that gives good results in one area may give poor results in another. Thus, it is necessary to try each test in the soil area for which it is to be used. Even then, there may be individual cases in which a test fails to show what is intended. However, if the test is standardized on the basis of field experiments, its limitations recognized, and is not used as the sole guide, it can be a reliable aid in measuring the fertility status of a soil.

Soils vary greatly in fertility levels—that is, amount of plant nutrients they contain. Much of this difference is due to past management practices as related to cropping, liming, and fertilization. However, these past practices have varied so greatly from farm to farm that a fertilization and liming program that does well on one field may not be satisfactory on another.

DETERMINING SOIL FERTILITY

Several approaches have been used in determining the fertility levels in soils. This has been done to make sure the proper rates and kinds of lime and fertilizer are applied. The most important of these approaches are discussed below.

Knowledge of the liming, fertilizing, and cropping history. Because of a lack of information, lime and fertilizer requirements can be predicted only approximately. This lack is due mainly to two reasons. (1) the difficulty in obtaining an accurate history from the farmer and (2) the difficulty in determining the losses of plant nutrients due to crop removal, soil fixation, and erosion.

Observance of deficiency symptoms of growing plants. Plants show symptoms of nutrient deficiency if the lack is severe enough. These deficiency symptoms give good leads as to the fertilizer requirements. However, these symptoms are often complicated by both disease and insect damage. Consequently, absolute identification of deficiencies may be difficult. In most instances, by the time the deficiency occurs, it is too late to obtain full benefit from fertilizer additions to that particular crop. In addition, plants may be mildly deficient and not show characteristic symptoms. Yet, yields might be increased by proper fertilization.

Tissue tests of fresh plant tissue. The plant is the end product of all the factors in the environment. Therefore, much information can be obtained from tests made directly on the growing plants. Of course, as in the case of deficiency symptoms, if the plant is found to be lacking in a given nutrient it usually is too late to obtain the greatest benefit from fertilization.

Soil tests. This method permits the soil to help answer the question concerning plant-food deficiencies, and in time to be corrected before the crops are planted. However, soil tests are most effective when used in conjunction with tissue tests, deficiency symptoms, and management history. The coordinated and careful use of these four tools should make for more effective and more efficient use of lime and fertilizer.

It must be remembered that poor crop yields are not always due to plant-food deficiencies. Merely applying the right amount of lime and fertilizer will not insure good crop yields. Careful attention must also be given to other management practices if maximum bene-

fits are to be realized from the lime and fertilizer applied. These include good crop varieties, proper cultural practices, correct seeding date, and control of weeds and insects.

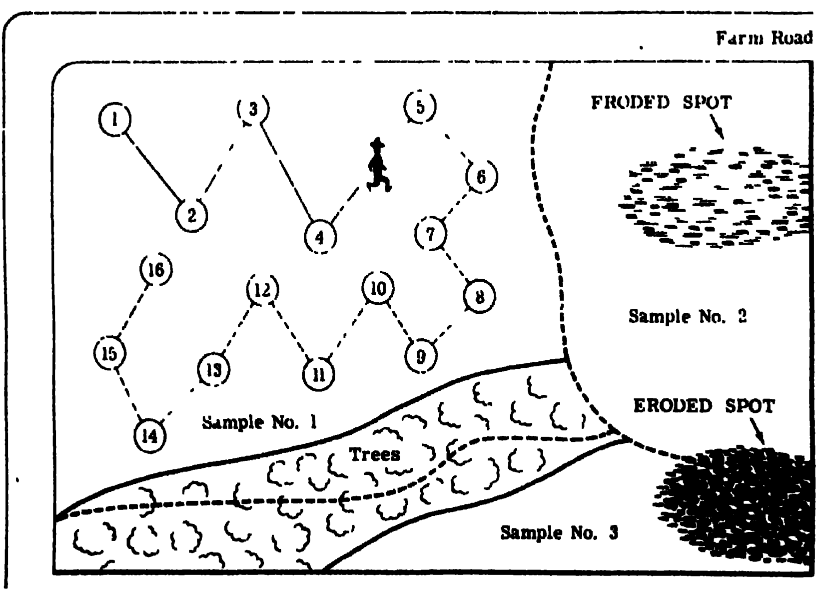
SOIL FERTILITY DIFFERS FROM PRODUCTIVITY

We know a lot about soil, but to date we can't tell much about its fertility by looking at it. However, we can determine its productivity fairly accurately from visual observations. For example, if soil is well drained, most crops will grow well. But if water stands on the land much of the time, the land is saturated and too wet for the best crop growth.

If the soil is stony, it is difficult to work. If the topsoil is thick, the plant roots have a larger storehouse from which to get their food and moisture. A soil may be well drained, stone free, and possess thick topsoil but be poor in fertility—that is, low in plant food.

However, the chemical or fertility status of a soil is not visible, so it is best learned by chemical analysis. Intensive research on meth-

Figure 8-1. In a non-uniform area, as shown below, Sample 1 would include level upland, Sample 2 would be taken from a sloping area, and Sample 3 from bottomland. Each sample is made up of fifteen to twenty borings taken as in Sample 1 and put in a one-pint container.



ods for determining quickly the fertility status of a soil has produced the commonly known quick tests.

SAMPLING SOILS FOR CHEMICAL TESTS

Undoubtedly, one of the most important issues associated with soil testing is the matter of obtaining a soil sample that represents the area to be tested. The instructions for soil sampling that follow are based on the type of procedure involving a composite sample from a given area. This is the sampling method in use by almost all states in this country.

How to take soil samples. For the purpose of sampling, the farm should be divided into areas or fields not larger than 5 to 10 acres in an area If an area or a field is uniform in appearance, production, and past treatment, it may include as much as 20 acres However, areas that are different in appearance, slope, drainage, soil type, or past treatment should be sampled separately, even though smaller than 5 to 10 acres (See Figure 8-1)

Figure 8-1 shows the method of properly locating the areas to be sampled Take a separate composite sample for each soil area or field. In taking samples a soil tube, soil auger, or narrow-bladed trowel are preferable, but with proper precaution a satisfactory sample can be taken with a spade and knife

Avoid taking the sample from the fertilizer band when sampling fields in row crops Avoid such unusual spots as old fence rows or roadbeds, or places where lime or manure has been piled or spilled Also avoid small areas that are much different from the rest of the field, if desirable, these areas can be sampled separately

The soil is easier to sample when its moisture condition is suitable for plowing Even though the soil is too wet to plow, it can often be sampled unless it is too muddy for handling The best time to sample is after plowing in advance of expected lime and fertilizer application

Any clods or lumps should be broken up before they dry out. Fairly wet samples can be spread out to dry at room temperature on a clean sheet of wax paper, however, don't dry samples on a stove or radiator

From fifteen to twenty spots over the field, take a uniform core (or thin slice) of soil from the surface of the plow depth (usually about five to six inches). (In permanent pastures or lawns, sample

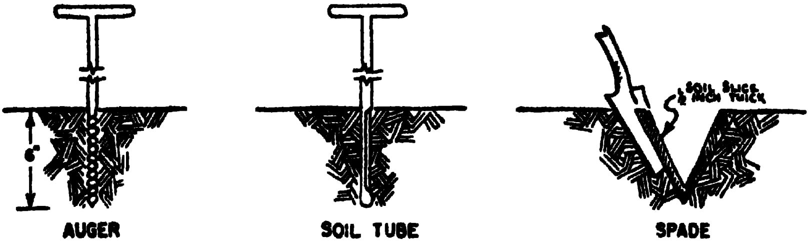


Figure 8-2. Use an auger, soil tube, or spade to take a soil sample to the right depth. (National Plant Food Institute Photo)

only to a depth of 2 inches.) If a spade and knife are used, dig a spadeful of soil to plow depth and throw it aside. Then dig a one-half inch slice of soil and keep it on the spade. Use the knife to cut from this slice on the spade a one-half-inch core from top to bottom, then place the core in a clean bucket or container. Repeat this at each of the fifteen to twenty spots.

If you are using a sampling tube or soil auger, it may be possible for the amount of soil from each spot to be such that a pint carton will hold the soil from fifteen to twenty spots. If this is not practical, such as with the spade, collect in a clean bucket. Mix the soil well from all spots, then halve or quarter as necessary to fill a pint carton.

Label each sample with a number and your name. Be sure to keep for yourself a record of the area from which the samples were taken. One way is to make a rough sketch or map of the sampled areas. Fill out the information sheet as fully as possible, because this will help greatly to make your report and recommendations useful to you.

Alkali areas are quite numerous in some localities. Alkali salts move up and down in the soil with the moisture, therefore, alkali areas should be sampled in one-foot layers. The sampling should be done to a depth of three feet or to the water table if encountered at a shallower depth. A soil auger can be used and composite samples obtained for each one-foot depth. This should be done in a manner similar to that used for surface soils. In addition, a sample of the surface crust itself should be taken and submitted for analysis.

SAMPLING A FIELD

Several factors need to be taken into account in preparing to sample a field for soil analysis. In this discussion consideration is

given to each of these factors. Also, it explains and supplements the instructions for taking soil samples as presented here. Among the factors that have to be considered in preparing to sample a field for soil analysis are:

1. The decision as to the area to select for soil sampling, that is, what size area to sample, and whether to subdivide the field into smaller fields.
2. The number of borings, the distribution of the borings, and the relation of the size of the area to be sampled.
3. Depth of sampling.
4. The size of the final composite sample (one pint usually), and whether this should result from subdivision of a larger sample.
5. The moisture status of the area: is it too wet or too dry?

Selection of area to be sampled. In most instructions the area to be sampled is designated as a "field," which implies an area confined to one crop or bounded by a fence, stream, ditch, road, or some other line. Frequently the instructions suggest that a separate composite sample be taken for every five to ten acres, thus restricting the size of the field. Actually there is no good basis for such a restriction. Soil type and past management should be the chief factors

Figure 8.3 (left). Soil for the composite sample is put in a bucket for thorough mixing. (National Plant Food Institute Photo.)
Figure 8.4 (right). Composite samples of soil are put in pint ice cream cartons for shipment to the laboratory for analysis. (National Plant Food Institute Photo.)

in deciding the size of the area. It is conceivable that a 20-acre field relatively uniform in soil type and in past management could be sampled better as a unit than a five-acre field that varies in topography, degree of erosion, soil type, treatment, and other factors.

From a practical standpoint it may be argued that there is little to be gained by dividing a five-acre field for sampling. This is particularly true if the field is to be fertilized or limed as a unit. There is, however, the advantage that some information is obtained on the variation within the field.

Some farmers may prefer to concentrate their sampling sites in the poorer parts of the field, then the entire field can be treated. This brings the poorer areas up to maximum production, even though the better areas may receive a slight excess. In still other instances both good and bad areas within a field may be sampled separately. This enables the farmer to find out by comparison the cause of these differences within the field, thus the purpose for which the samples are taken will influence the selection of the area to be sampled.

Admittedly, the usual instructions dealing with field size are conservative on two counts: They both restrict the size of the area represented by one composite sample and specify the omission or separate sampling of smaller areas--areas that differ in topography, position, or past management practices.

Number and distribution of borings. Most instructions call for a composite sample made up of anywhere from five to twenty borings within a given field. If the field is subdivided because of differences in soil type, another composite made up in the same way should be taken.

Depth of sampling. Almost all emphasis in soil sampling for routine chemical tests has been placed on the topsoil sample. This sample is usually taken at the plow depth, or upper five to six inches, in fields that have been cultivated. It is obvious that plants obtain some nutrients from lower depths. However, in sampling soils one of the objectives is to sample the zone that is most likely to reflect past management, rather than the feeding zone of the plant.

In case of permanent pastures and lawns, instructions call for confining the sample to the upper two inches. This should not be taken to imply that grasses and legumes feed only in that area, because obviously they feed from lower depths, also. The upper two-

inch sample in this case is based on correlation of results of analysis with need for lime and fertilizer. Where lime and fertilizer are added on top by broadcasting, there is a better relationship between the plant-food requirements obtained by analysis of the upper two inches than of the six inches. Where pastures are plowed or cultivated, these instructions need to be qualified.

Size of sample and subdivision. The average soil-testing laboratory calls for a volume of from one pint to one quart of soil. This may contain a certain amount of trash and rock material, so when the soil is dried and prepared for analysis the trash and rock material may amount to half the volume. Some instructions call for a small quantity of soil at each boring site to hold the composite sample to the pint-to-quart volume. Other instructions call for a composite amounting to several times this volume. The larger samples are mixed and subdivided.

There is always the likelihood of improper mixing with large samples, which is especially true if the soil is damp. It would be preferable to avoid subdividing. Use a sampling tool that takes a small volume from each site. In this case the composite of all borings is included in the pint-to-quart volume. In practice, this involves difficulties, consequently many instructions call for a composite sample whose total volume is from one to two quarts. This is thoroughly mixed by hand. From one-fourth to one-half of the total volume makes up the sample for analysis.

Moisture status. One other factor that deserves mention is the moisture status of the field when sampling soils. Little information is available on this. Most instructions do not recommend sampling fields that are very wet, because it is difficult to sample and properly mix wet soils. In addition, wet samples sent into the laboratory may easily be contaminated en route. When they dry out in the container they may be difficult to handle. In spite of this, to avoid conflict with other farm work, it is sometimes necessary to sample fields too wet to plow. Such samples should not be dried artificially but should be allowed to air dry so they can be broken up by hand and halved, if necessary.

INCLUDE INFORMATION ABOUT THE SOIL

Any information supplied with the sample is helpful to the person making the test. The soil type name, if known, characterizes the

soil. It tells something about its physical and chemical properties useful in the interpretation of the tests.

The cropping history and soil treatment for the past three to five years provide useful information: Has the soil ever been limed, have fertilizer and manure been used? Are the kinds and amounts known? Is manure available now for use on the soil? Also, what crops are going to be grown?

Other factors on which information is useful include the amount of drainage; whether or not the land is hilly, rolling, or level; whether or not there is material underlying the soil, such as sand, gravel, or bedrock; and the approximate size of the area represented by the sample.

TIME OF SAMPLING

The soil is constantly changing. It is teeming with millions of microorganisms. Their activities vary from day to day and from season to season and also change with changes in temperature, moisture, and food supply. A rapid-growing crop drains soil of its available plant food. Consequently, soils are low in available plant food at the end of the growing season, unless the amounts of these materials added in the fertilizer, or becoming available in the soil, are in excess of crop demands. Seasonal fluctuations in soil acidity influence the availability of plant nutrients to some extent. Acidity is normally at a minimum in early spring and at a maximum in midsummer.

For general soil diagnosis, tests on samples taken in early spring are most reliable. Tests in the autumn after the crop is harvested indicate whether or not the fertilizer has been in excess of crop needs. Fall testing has the added advantage of allowing ample time to obtain materials and make plans for spring work. The choice of time for taking the sample depends, therefore, on the purpose for which the test is made.

INTERPRETING SOIL TESTS IMPORTANT

Simple chemical soil tests often provide us in a few minutes with more useful information about the fertility of a soil than can be learned by several days of detailed laboratory analysis. The results of the tests can be used by a competent person to make sound soil-management recommendations, but are often misleading to those

who have little understanding of the relationships between soil chemistry and plant nutrition

Soil testing is only another tool used in diagnosing soil ills It is not infallible In the hands of inexperienced people great harm may be done soils from incorrect interpretations of the tests For example, inexperienced people might recommend liming when actually sufficient calcium was available in the soil Overliming may produce minor element deficiencies

Practical interpretation of soil tests should be considered in the light of known limiting factors on crop growth for the soil being tested These limiting factors include poor soil aeration, poor soil structure, deficient drainage, low organic matter content, unfavorable seasonal conditions, plant pests, and plant diseases

HOME SOIL TESTING

Portable kits for testing soils are available for home use Generally they will do a good job of testing, but most people do not have the experience or the training to interpret the tests correctly Results with home kits may often be disappointing

But soil testing need not be done in the home Nearly all the state agricultural experiment stations, a few county extension directors, and some commercial firms, like fertilizer and seed companies, farm management specialists, commercial laboratories and canners, make tests A small charge is made for this service by some Usually, the people in charge of the testing are competent soil scientists and are qualified to interpret results of the tests and suggest correct treatment of the soil

Soil samples may be taken to a soil testing laboratory or mailed In either case, be sure to give as much information about the soil as possible This insures the best possible interpretation of the test results and recommendations of proper treatments by the soil scientist

USES OF SOIL TESTS

Lime requirements. Soils vary greatly in acidity as well as in texture and organic matter content These factors affect the amount of lime needed A soil test is the best guide in determining whether or not lime is needed and, if so, how much Soil tests are helpful in pointing out where the lime would be most beneficial

Fertilizer requirements. The general recommendations of state agricultural experiment stations or extension services are of necessity based on average soil conditions. In many instances ranges in grade of fertilizer and in rate of application are given. Since soils vary greatly in fertility level, each field must be considered a separate problem. Soil analyses help the farmer to choose the proper grade and rate of fertilizer, thus enabling him to correct for low levels of either phosphorus or potash in the soil.

Determination of the amount of organic matter in the soil is important in the fertilization of certain crops. When organic matter decomposes, it releases nitrogen. With a crop like flue-cured tobacco, which is damaged by too much nitrogen, the amount of nitrogen required in the fertilizer is greatly affected by the organic matter content of the soil

HOW SOIL TESTS CAN HELP

Soil tests assist farmers in several ways. They indicate the amount and kind of fertilizer and lime that should be applied to a certain crop when grown on a certain soil. Often they can be used to determine which of two or more available fields are best suited to the growth of a specific crop.

Combined with plant tissue tests, soil tests are excellent diagnostic tools for trouble shooting when a crop fails to grow satisfactorily.

Soil tests also provide an excellent control method for determining plant food losses during heavy rains. In such instances, nutrients lost from the soil can be replaced before the crop begins to suffer deficiencies. Potato growers in New Jersey have profited from such use of soil tests, in recent years.

Exercise

1. Draw a rough sketch showing the boundaries of a field on your farm. Use a soil map or aerial photograph if available. If the soil is not uniform throughout the field, draw lines through the sketch to locate the areas to be sampled. Take an appropriate sampling tool and get a composite sample of each of the sampling areas. Have the samples analyzed for fertilizer and lime recommendations for the field.

Questions

1. What is soil testing? What is its purpose? Why is it necessary?
2. What is soil fertility? How does it differ from productivity?

3. Are poor crop yields always due to lack of plant food? Name other factors that may cause poor crop yields.
4. What is the main objective to be achieved in taking a soil sample for testing?
5. What are the main precautions to be observed in taking soil samples?
6. How many borings should be made in sampling an area? How is the composite sample obtained?
7. How do we determine the size of the area to be sampled? How do we proceed in taking the sample?
8. What tools are used in taking soil samples? Name the good and bad points of each.
9. Explain the various steps in sampling a field or sampling area.
10. Explain how soil test results are used.

9

Land Judging

A NEW type of contest, based on the axiom "experience is the best teacher," is teaching our youth how to save soil and improve our land. It offers young farmers a new approach to sound land use and safe farming.

The purpose of these "schools" is to teach young people how to make the best use of their soil, how to determine what the land is best suited for, and how to use management methods best suited to controlling erosion and improving the soil.

PROGRAM FOR YOUNG PEOPLE

The program is aimed primarily at our young people, especially the 4-H Club members, Future Farmers of America, and GI agricultural trainees. However, many groups of adult farmers are getting much useful information from the exercises. These contests grew out of annual soil conservation schools for 4-H Club and Future Farmers of America. The schools were held at the Red Plains Conservation Experiment Station, Guthrie, Oklahoma, and were started in 1941.

At first, the meetings were called "field days" and were handled as schools. The "students" identified plants and studied soil profiles. These meetings soon showed a need for a more practical and effective method of teaching good soil management. The results of these schools showed that this was an excellent way to stimulate interest in sound soil management. Members of winning teams were con-

sidered by other contestants as leaders in the field, just as winners in livestock and other judging contests are considered leaders in those fields

Land judging is a new tool developed to teach fundamentals of proper land use It is designed to give more people a better understanding of the fundamentals of the land, and is rapidly becoming an outstanding teaching method because it enables the student to

Figure 9-1 Students learn about soil in the field A class in land judging in Oklahoma (Oklahoma A & M College Photo)

learn by observing and examining the soil He then associates his new knowledge with good soil management practices

Land judging helps develop an understanding of soil conservation The contests point out the difference in land and land needs for tomorrow's farmers The judging is done in much the same way as that of livestock In judging livestock for beef we look for those characteristics that make for lots of beef depth of body, straight

Figure 9-2. Oklahoma 4-H Club girls show interest in land judging too. (Oklahoma A. & M. College Photo)

topline, smoothness, and other characteristics. In land judging we look for those characteristics that affect crop yield: soil texture, permeability, slope, amount of erosion, depth of topsoil, and so on. In both types of judging the characteristics present must be recognized, and decisions must be made as to their effect on production.

Land-judging contests are a tool that can be used to teach farmers and landowners to recognize the importance of their land. Developing enthusiasm through the spirit of competition, it becomes a spark that helps light the fires of knowledge in the field of scientific farming. Land judging literally helps the student to "learn by doing."

Land judging has proved to be a truly great teaching aid for a subject that many young people find most difficult. Helping to point the way to intelligent soil and land management, land judging is fundamental to a sound, prosperous agriculture.

OUR LAND-LOSING PLANT NUTRIENTS

Because of continuous cropping and erosion, our once fertile soils are rapidly losing plant nutrients and organic matter. As our soils deteriorate the need for fertilizer increases, which gives rise

to many new problems because water is often the factor limiting crop production. Fertilizer responds in proportion to the amount of available water present, so this makes intelligent land use and good farming practices a must. That is why the use of fertilizer and lime is included in land-judging contests.

Fertilizer helps conserve soil and water by producing more plant material. Good farming, therefore, provides for the best and fullest productive capacity of the land. Good use of the land is based on our understanding of the land—understanding of land capability and Nature's methods of developing and maintaining soil, water, and plants. The most effective and practical means consists of a combination of a number of factors: sound land use, water control, soil improvement, crop selection, and farm management. These factors are stressed in land judging contests and shown by the National Land Judging Score Card.

LAND JUDGING CONTESTS

Land judging contests consist of two parts. Part One consists of the land class factors that determine the land capability class. Part Two provides for the selection of proper land treatments and ranges from the selection of vegetative and mechanical practices to addition of sufficient fertilizer and lime.

From a careful analysis of the soil profile and the necessary treatments, the student is able to arrive at proper methods of controlling

Figure 9-3. A land judging contest under way in Oklahoma. (Oklahoma A & M College Photo)

erosion and runoff. He can also improve soil fertility by selecting the management practices necessary to maintain continued maximum crop production.

Four fields judged. Four fields (usually numbered 1, 2, 3, and 4) are generally used in each contest, and each field represents a different land capability class. Pits are dug in each field so that the contestants can examine the soil. A generous sample of both surface and subsoil of each is then placed near the pit for closer observation.

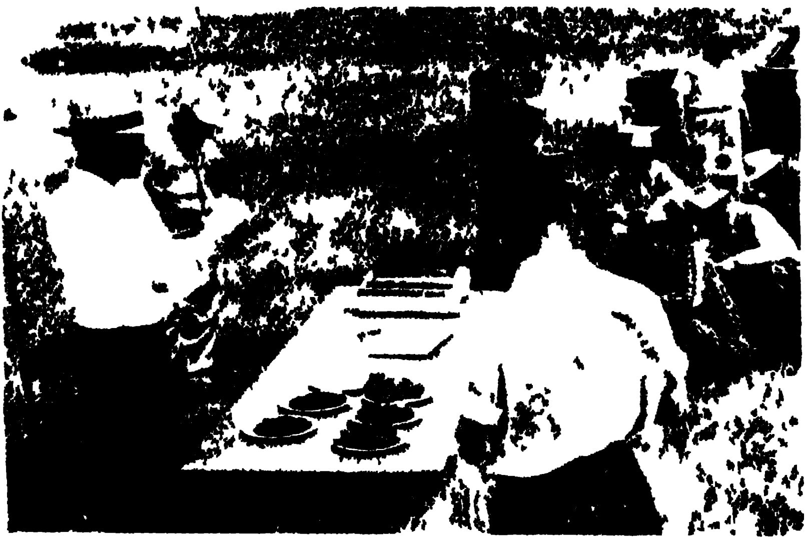


Figure 9-1 Students from the I. J. Training School in Oklahoma classifying land on basis of soil samples taken from several locations
(Oklahoma A. & M. College Photo)

Field force. The field personnel consists of a contest chairman, a supervisor, and a guide for each pit in the field. The chairman explains the rules and issues instructions concerning locations of the four fields, the supervisors give needed information for each group visiting the field, and the guide escorts the contestants from one field to the next. Groups are usually limited to twenty-five or thirty contestants.

Operation of contest. The contest is composed of competing individuals and teams. Each team consists of four members, with one

of the four an alternate. The three high scoring members constitute the team.

The contestants are given land-judging score cards for each field. The cards are numbered for teams 1, 2, 3, and so on. The individual members of teams are designated as 1A, 1B, 1C, and 1D. Teams 2, 3, and so on are assigned likewise. Contestant 1A starts at Field 1, 1B at Field 2, 1C at Field 3, and 1D at Field 4.

In general, Part 1 of the score card is based on six easily identified soil factors. Part 2 is based on the selection of proper soil and crop management practices, which include selection of proper plant cover, mechanical treatments and fertilizer necessary for the different land classes.

Land factors. If the land is or has been in cultivation, the original topsoil depth and other soil conditions are given each contestant as he visits the field. He then decides whether the soil is deep, moderately deep, shallow, or very shallow. By feeling the soil in his hands he determines whether the texture is coarse, medium, or fine.

By handling the soil to see if it is crumbly, dense, loose, or tight, the movement of air and water in the subsoil, or soil permeability, is determined. The movement is then classified as rapid, moderate, slow, or very slow. Then the topography of the land is observed to decide whether it is nearly level, level, gently sloping, moderately sloping, steeply sloping, steep, or very steep.

The contestant next examines the topsoil to see how much of it remains; on the basis of this, he determines the amount of soil removed by erosion. He then classifies the erosion damage as very severe, severe, moderate, or slight. Finally, he checks the drainage to determine whether it is poor, fair, good, or excessive.

When the above mentioned factors have been rated, the contestant decides in which land-capability class the field belongs.

Land-use treatments. After determining the land-capability class, the contestant decides which practices are needed for proper treatment. Some of the land will need lime or fertilizer, so a sign showing the results of a previous soil test is set up in each field to enable contestants to determine these requirements.

A large number of practices are listed on the score card for use in selecting the vegetative, mechanical, and fertilizer treatments. Only part of the practices apply to any field. Each possible treatment is numbered on the card, and the appropriate number is selected and placed in a square under Part 2 of the score card. (See Figure 9-5.)

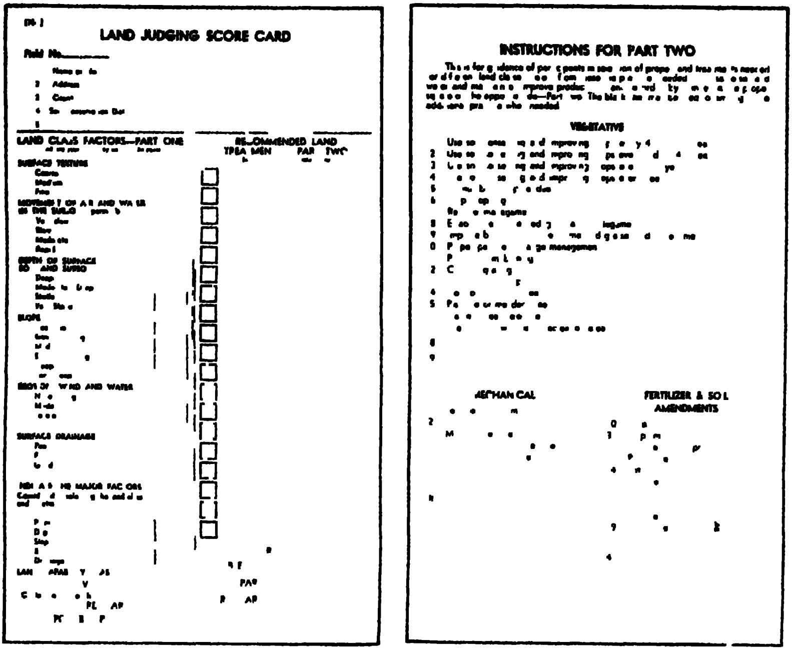


Figure 9.5 National Land Judging Contest Score Card (Oklahoma Agricultural Extension Service Photo)

When the contestants finish judging a particular field, their cards are collected by the guide and given to an individual who takes them to headquarters. The cards are then graded according to the official placings of the judging committee. The scores are tabulated by a grading committee, which is usually composed of the coaches of the individuals and teams and members of local agricultural agencies.

A perfect score is 60 points for each field, 240 for the contest. Winning individuals or teams are those earning the highest number of points.

RANGE JUDGING

Land judging principles can be applied to grassland management as effectively as to land that is devoted to cultivated crops. Score cards have been designed for use on range or native pasture, and are based on the same principles as the score cards used for rating cultivated cropland.

Judging of grassland begins with identification of native range or pasture vegetation. This is followed by a study of range conditions,

range sites, degree of utilization, value of range plants and their relationship, mechanical practices, tame pastures, kind of plants to use, seedbed preparation, planting methods, fertilization, and management.

Placing sheets. Placing sheets have been prepared for (1) Range Condition Classification and Treatment, (2) Range Plant Identification and Evaluation, (3) Native Range Plant Identification, and (4) Pasture Judging. A site consisting of a circular area about 40 feet in diameter is used for judging grassland pastures. The object is to determine (1) the kind of grassland, (2) how hard it has been used, (3) its condition, and (4) treatments needed to protect and improve the native grassland.

In scoring this sheet, 30 points are allowed for correct answers under each of the three main divisions: (1) degree of utilization, (2) kind of site, and (3) range condition.

Rangeland is divided into five classes on the basis of the degree of utilization: unused, light, proper, severe, and destructive. The site is divided into four classes: bottomland, ordinary upland, steep slopes and ridges (or shallow soils), and savannah. Range condition is divided into excellent, good, fair and poor. An additional 40 points are allowed for four practices, because each practice rates 10 points.

The second phase of the contest is range plant identification and evaluation. The site for this study may be any convenient place where native range plants are displayed. The plants are dug up prior to making the study, so that the contestants can identify the plant and describe its characteristics. Five points are allowed for the correct name of a plant and each of its four most important characteristics.

The third phase of the contest is native range plant identification. Living plants, growing naturally in the ground, are used, and the object is to identify twenty range plants. Each plant is allowed 5 points.

PASTURE JUDGING

Part 1 of the pasture-judging score card is similar to the land-judging card. Part 2 is used to determine the method of establishing and managing a tame pasture.

Start with soil profile. The starting point in the study of land is to look at it on a profile basis in the field. Here the student can feel the soil in the several horizons and see what the plants look like that are

growing on it. He can also examine the environment in which the land is located.

In land judging, farmers and farmers-to-be are taken to the field and taught some of the fundamentals of soils in relation to their capabilities. Land judging is a visual method of teaching to impart ideas upon which sound systems of soil management can be developed.

MANY FACTORS AFFECT PRODUCTIVITY OF LAND

Many factors enter into the productivity of a piece of land. Likewise, many conditions dictate the management practices that should be employed on it. Certain level, well-drained lands are Class I lands, if the texture is loamy, if they have a reasonably high organic matter content, and if they have a well-defined and well-stabilized structure. However, they must be free of stone and other obstructions and located in a climatic environment with suitable rainfall, sunshine, and temperature.

Class I land is the easiest to manage. Mistakes made in management may not cause serious trouble unless repeated many times. Class I land can be planted to virtually any crop desired, with the assurance that it will produce good yields even under minimum management experience. But, as the land deviates proportionately, in any respect, from these desirable characteristics it falls into a more troublesome class and requires better-than-average management practices.

If it deviates enough in any one, or all, of these conditions it may be suitable only for hay or pasture. In this case, it can stand only a limited amount of cultivation, and on a carefully controlled basis at that. Even under these adverse conditions, however, it can often be profitably farmed, provided the right kinds of crops are chosen and the right kinds of management are employed.

GOAL OF LAND JUDGING

The goal of land judging is to teach the student, both young and old, to recognize the factors inherent in soils that determine their capabilities and get them to understand how they operate. Students are taught to recognize where and how far the conditions at hand deviate from the ideal. They are taught also what effect these deviations have on soil management and cropping practices, and learn that management practices and crop selection must be adjusted to the various classes of land for economic returns. This is true not only for

the current year but also for over the period of a lifetime, and longer. In short, the soil must be so managed by methods adapted to the land that it will not only be kept intact, but also its productivity will be increased.

Practice in land judging soon leads to the realization that not only can poor land be made more productive, but also that the best land can be made better.

EXERCISE

1. Select four locations on your farm that differ materially in land characteristics. Unless there is a gully bank, road cut, or ditch running through them, dig a hole about four feet deep in the ground in each location. (This is done to expose the soil profile.) Examine the soil carefully, in the different soil horizons on the four locations, for the following characteristics:

a. Rub some soil between your thumb and finger to determine texture. Is it coarse, medium or fine?

b. Examine the soil carefully for permeability—movement of water and air. Is it very slow, slow, moderate, or rapid?

c. Measure the depth of the topsoil. The topsoil is the surface soil and is usually dark in color. Is it deep, moderately deep, shallow, or very shallow? Make similar measurements of the subsoil.

d. Determine the slope of the land. Is it nearly level, gently sloping, moderately sloping, strongly sloping, steep, or very steep?

e. Determine how much of the topsoil remains, so that you can tell how much of it has been removed by erosion. Is erosion none to slight, moderate, severe, or very severe?

f. Check the drainage. Is it poor, fair, good, or excessive?

g. Now determine the land capability class of each location. Use a score card for this entire operation.

QUESTIONS

1. What is land judging? What is its main purpose?
2. Who is the program aimed at? How did the program originate?
3. How is land judging taught? How does it help understand soil?
4. What are the main points emphasized in land judging?
5. Explain how land-judging contests are conducted.
6. What are the chief land factors studied in land judging? How does each affect soil productivity?
7. What is the goal of land judging?
8. Why is it necessary to start with soil profile?
9. How does the land-capability class determine treatment measures to be used?

10

Plant Cover

In building soil, Nature does two things at the same time: She holds the soil where it is formed, and she builds the soil deeper. The first of these we call "holding" action; the second, "developing." Plant cover is used to accomplish both.

To assure success in both operations, Nature created a vast number of kinds and types of plants—so vast that there is a plant suited for nearly every conceivable set of conditions. Nature develops in order the most suitable plants for each combination of soil and climatic conditions.

Throughout the soil-building process, the ground surface is covered with a blanket of plant growth, which holds the soil in place. The lowest forms of plants, such as lichens, are usually used to start the soil-building process. Lichens are especially suited for the job, because they are flat, rootless plants; they can grow in places where no higher forms will grow; they thrive anywhere, except in areas of perpetual snow; and they can live on naked rock. Lichens are usually the first living things to appear on barren ground, and, as they grow and reproduce, they develop conditions suitable for higher forms of plants.

The lichen's ability to live on rock is due to its particular nature. In reality, lichens are two plants but act as one. Each is a separate plant, in that one is an alga, the other a fungus. Each is unlike the other, but neither can survive without the other. The fungus produces acids that dissolve the rock, which supplies needed plant food to the alga. The alga uses this plant food in its growth to produce or-

Figure 10.1 Formation of residual soil in state park near Ottawa, Illinois. Generations of lichens growing on solid rock have gradually brought about decomposition of the surface portions of the rock. The addition of organic matter in the form of decaying remains of lichens has caused the formation of about one half inch of soil. Peeling back the lichens from the rock surface picks up the soil. (Soil Conservation Service Photo)

ganic matter without which the fungus would die. This organic matter also becomes mixed with the decaying rock to form soil.

Over the rock surface lichens form a protective covering that catches dust. It also holds the soil in place as it develops from the surface downward. Eventually enough soil is developed on the rock surface to support higher forms of plant life. As this condition approaches, lichens are gradually replaced by the next higher form of plant life. Further improvement is followed by the invasion of still higher plant forms. Finally, the highest form of plant life the soil and climate will support takes over.

Throughout the soil-building process there is enough plant cover to protect the ground from water and wind. When man removes or reduces this cover, there is not enough to protect the surface, and the soil erodes and deteriorates. The succession of plant life active in building the soil is upset. As soil conditions grow worse, lower forms of plant life invade the area. That is why, for example, we have

weeds in cultivated fields—plowing the soil throws the plant succession back to the weed stage.

The holding action of plant cover on the soil was not recognized for a long time. It was not known to exist until Nature's balance between soil-building and soil-destroying forces was upset by removal of plant cover. Removal of native plant cover exposed bare soil to the full force of water and wind, and the damage that followed stopped the soil-building process. The trend was changed to one of soil destruction. Even now, few realize that the holding action is necessary for soil and water conservation and, in turn, soil improvement.

PLANT COVER ABSORBS ENERGY OF FALLING RAINDROPS

For hundreds of years, it was thought that the main thing plant cover did in controlling erosion was to slow down water flowing over the ground surface. We know now that is only of minor importance. The main way that plant cover, outside of channels, prevents water erosion is by catching the falling raindrops before they strike bare ground. It acts like a cushion or shock absorber, by catching the falling raindrops and removing their energy or power.

Raindrops broken up by plant cover and eased to the ground as clear water cause no damage. They neither destroy soil aggregates nor seal the surface, and their water is absorbed freely by the soil. Soil Conservation Service workers showed the main function of plant cover was in de-energizing falling raindrops rather than slowing down flowing surface water. This was proved by making artificial rain.

At Coshocton, Ohio, artificial rain was applied to three series of plots at the rate of two and a quarter inches per hour. After plowing, the plots were left bare and exposed to the action of natural rain for some weeks. (During this period the surface soil became crusted and sealed.) Two of these series of plots were then covered with straw, which was used at the rate of two tons per acre.

In one series, the straw was placed directly on the ground. In another, it was supported 1 inch above the surface of the ground on chicken wire. The third series was left bare. Artificial rain was then applied at the rate of two and a quarter inches per hour for a twenty-minute period. They found that 92.7 per cent of the water

applied ran off the bare plot. Runoff on the plot with the straw placed on the ground was 65 per cent. Where the straw was supported one inch above the ground the runoff loss was 83.2 per cent.

The corresponding soil losses for the three plots were 5.62 tons per acre for bare ground, 0.42 ton for the first mulched plot, and 0.26 ton where the straw was supported one inch above ground.

The mulch was not very effective in controlling runoff, when applied after the surface of the ground had been sealed by raindrop impact It did reduce the rate of soil loss substantially, though. Had surface flow been the chief factor in bringing about erosion, the second straw plot should have lost much more soil than the first. However, there was little difference in soil loss from the two straw-covered plots.

Further light was shed on this point by use of two additional series of plots. In this case, the surface soil was broken to a depth of about one inch and covered with straw immediately. Straw was applied at the rate of 2 tons per acre. In one series, the straw was placed directly on the surface of the ground. In the other, it was supported one inch above the surface on chicken wire. Water was applied at the rate of two and a quarter inches per hour for twenty minutes.

The mulch in this instance almost completely eliminated both runoff and erosion. The plot with the straw placed on the ground surface lost 1.7 per cent of the water applied and 0.1 ton of soil per acre. The other plot lost 1.2 per cent of the water and 0.12 ton of soil.

These studies show that the chief function of the straw was energy absorption. It had protected the ground from the impact of falling water drops, and damage from overland flow was insignificant.

TYPE OF PLANT COVER IMPORTANT

Plant cover controls splash erosion by catching the falling raindrops and absorbing their energy, which is like taking the powder from a shotgun shell before trying to fire it—it wouldn't have power enough to push the shot out of the gun. The caught raindrop doesn't have the power to blast the soil—it can't erode soil.

Effectiveness of plant cover in preventing erosion depends on the amount present and how well it is scattered over the surface of the ground. Both weight, in terms of pounds per acre (dry weight), and

coverage, in terms of percentage of the ground surface covered, are important.

Weight determines the amount of cover available to absorb the energy of the falling raindrops, or, how much of a cushion there is to absorb this force. The evenness of distribution over the surface of the ground determines how much of the ground surface is actully protected.

The type of crop is also important. Low, thick-growing plants like most grasses and many clovers are more effective than taller growing crops like wheat and oats In turn, wheat and oats are more effective than tall-growing crops like cotton and corn.

Grasses and clovers generally completely cover the ground and don't leave any of it exposed to falling raindrops Such crops as wheat and oats do not make as thick a growth, so they allow some raindrops to get through These strike the ground directly

Coarse, tall-growing crops like corn and cotton are spaced far apart and allow many raindrops to get through And, too, the water from the drops they catch on their leaves forms larger drops, which fall to the ground from the tips of the leaves These large drops may actually do more damage than the raindrops that the cover caught, because they are larger and have more weight When they strike the ground they splash more soil

As crops get coarser and taller, larger amounts of crop material are needed for complete protection Because the plants grow up into the air, they do not spread sidewise over the ground or catch as many raindrops as low growing plants that cover the ground better

With low, close-growing crops, such as most grasses and clovers, 2,000 to 3,000 pounds per acre may be enough For crops like wheat and oats, 3,000 to 4,000 pounds may be needed Still larger amounts are needed for coarse, tall-growing crops like cotton and corn.

All plants have equal value in preventing erosion as long as there is no more than 1,000 pounds per acre This is because the tall-growing plants are small and their tops are close to the ground As the amount of cover increases beyond 1,000 pounds per acre the difference in value of types of plants shows up This difference becomes greater as the plants grow older and taller

IMPORTANCE OF CLOSE-GROWING CROPS

The effectiveness of any cropping system in reducing soil and water losses depends largely upon the proportion of close-growing

vegetation used, and the length of time and season of the year when it occupies the land. Crops that provide protective cover during the months of erosion-producing rains are especially valuable for conserving soil and water.

Land in Georgia, planted continuously to cotton, lost an average of 24.95 tons of soil per acre annually during an eight-year period. Using a two-year rotation cut this loss to 15.39 tons. The rotation

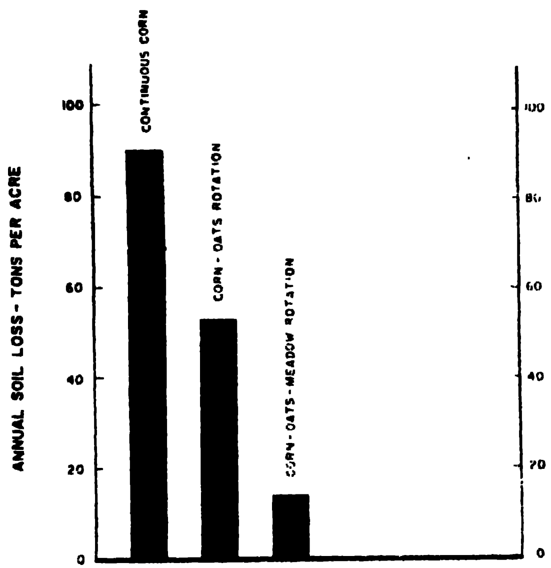


Figure 10-2. Effect of cropping practices on erosion of Shelby silt loam in Missouri.

consisted of corn-crotalaria and cotton-vetch. A three-year rotation of oats-lespedeza, lespedeza, and cotton reduced erosion to 3.38 tons per acre annually. Of the 10.15 tons of soil lost per acre, during the three years of the crop rotation, 7.08 tons were lost during the year the land was cropped to cotton. Only 0.25 ton was lost when the land was in lespedeza.

From April to September, unmulched land in Georgia lost 12.57 tons of soil per acre, and mulched land lost only 0.2 ton. Unmulched lost 32.75 per cent of the rain as runoff, and the mulched land lost only 1.43 per cent. Disk-harrowed land planted to Kobe lespedeza, and mulched with straw, lost 1.2 per cent of the rain as runoff, as

well as 0.24 ton of soil. A similar plot unmulched, lost 24.2 per cent of the rain as runoff and 12.62 tons of soil per acre.

A continuous cotton plot in Mississippi lost 58 per cent of the rainfall as runoff. The study covered a two-year period. There was a total rainfall of 130.7 inches. As much as 96 per cent of the water ran off during some rains. Soil loss on this plot exceeded 195 tons per acre for the two-year period. The runoff from broomsedge in an old field was only slightly more than 1 per cent of the rainfall. It was even less from an oak forest. Runoff from these two classes of cover during individual storms did not exceed 5.05 and 3.10 per cent of rainfall, respectively. Erosion was almost negligible on both. Cultivated land lost 4,300 times as much soil per acre as the forested plot.

CONSERVATION OF PLANT NUTRIENTS BY PLANT COVER

Total amount of soil lost by erosion tells only part of the story. Soil erosion has been shown to be a selective process that is, it decides what part of the soil it will take first. (This is just the same procedure you employ when you go to the dinner table: You select what you wish to eat first.) As a result of this selection, soil removed by erosion usually contains higher amounts of organic matter, silt, and clay than of coarser materials. Except in extreme cases, the material removed by erosion contains much larger amounts of plant food than the soil from which it came or the soil that is left.

Examinations made in Wisconsin recently showed the concentration of nitrogen to be higher in the eroded soil material in each instance than in the parent soil. It was several hundred per cent higher in many instances. Losses of soil and plant nutrients were closely related to the amount of plant cover.

The selectivity of the erosion process is also well illustrated by the results of a single storm in Idaho. The surface soil lost 6 per cent of its silt, 7 per cent of its clay, 20 per cent of its organic matter, and 20 per cent of its nitrogen. The surface soil contained 3.05 per cent of organic matter before, and 2.44 per cent after, the hard rain. The eroded material contained 5.35 per cent.

CONSERVATION OF ORGANIC MATTER BY PLANT COVER

Erosion quickly removes organic matter from the soil. This is particularly true where there is not enough plant cover to protect the

soil from the impact of raindrops. Without the protection of plant cover, it is difficult even to maintain the organic-matter content of the soil. It is needless to try to build it up.

This received positive proof from studies conducted on Shelby silt loam in Missouri during a seven-year period. Soil and organic-matter losses through erosion were found to be in reverse order to the amount of plant cover. For example, the organic-matter content of soil kept in fallow declined from 3.76 to 2.49 per cent during the seven-year period. But, throughout the same period it increased from 3.65 to 3.91 per cent in land kept in sod. The organic-matter content of soil planted to continuous corn declined from 3.31 to 2.64 per cent. Land planted to a three-year crop rotation of corn, wheat, and clover showed a decline of from 3.52 to 3.42 per cent. Without the protection of plant cover, it is impossible to keep the organic matter from being lost.

INFILTRATION INCREASED BY PLANT COVER

The sharp impact of raindrops, as they strike bare earth during heavy rains, shatters the clods and soil crumbs and breaks down soil structure. The beating, churning action of these drops compacts the fine soil particles into a nearly impervious layer of surface mud. This we call "puddle erosion."

The compacted surface layer becomes denser and more nearly impervious as it strains colloids and other particles from the turbid rainwater that filters down from the surface. This layer is the most important factor affecting the intake of water by the soil. It decreases infiltration, increases runoff and soil loss, and paves the way for gully formation.

Puddle erosion can be prevented The solution is to keep enough plant cover on the surface to protect the soil. This cover may be composed of growing plants or plant residues, or both. It is extremely important to have enough cover, well distributed over the surface. This will keep the beating raindrops from breaking down soil structure and prevent puddle erosion.

The Missouri studies indicate plant cover is an important factor in maintaining favorable moisture conditions in the subsoil. Beneficial effects of sods turned under have usually been credited to an improved supply of nitrogen. The important factor seems to be the accumulated moisture in the subsoil. Grass crops absorbed 87.4 per cent of the rainfall; a three-year rotation with one year of sod ab-

sorbed 85.5 per cent; and land continuously in corn absorbed only 69.6 per cent. These are averages for a fourteen-year period.

This was the equivalent of an increase in rainfall of 7.2 inches for land in grass. It was 6.4 inches for land in the three-year rotation—that is, land in grass absorbed 7.2 inches more water annually than land in corn. Land in the three-year rotation absorbed 6.4 inches more. This water would have gone a long way towards producing a corn crop, especially since two-thirds of the rain came during six months of the growing season—or the period when differences in rainfall mean differences in yields.

Much of the extra water moves beyond the root zone of the grass, and is stored out of reach of the grass. Thus, the soil layer—such as the 24- to 36-inch layer—beneath the grass roots contains more water than the same layer under cultivated soil. Moisture in two similar soils, not far from those cited above, are interesting from this standpoint. This is true for a three-year period, which was a period of deficient rainfall. Table 3 gives the moisture content, as the percentage of moisture in the successive one-foot layers, to a depth of three feet.

TABLE 3

MOISTURE CONTENT AT SUCCESSIVE DEPTHS UNDER SOD AND UNDER CULTIVATED SOIL IN MISSOURI

0–12 Inch		12–24 Inch		24–36 Inch	
Sod	*Cultivated*	*Sod*	*Cultivated*	*Sod*	*Cultivated*
(per cent)	(per cent)	(per cent)	(per cent)	(per cent)	(per cent)
27.18	25.23	29.90	24.61	26.11	16.58
33.80	31.70	31.90	30.80	32.60	24.80
26.30	27.80	28.20	28.90	28.30	23.00
27.00	26.80	28.50	27.30	27.80	19.80
32.90	28.30	30.00	28.60	30.70	23.40

The 24- to 36-inch layer was much drier in the cultivated soil. Considerable time always elapsed after rain before this layer regained moisture; consequently, total water content of this layer in cultivated soil never equaled that in the 24- to 36-inch soil depth under sod. The 0-12 inch layer under sod had a moisture content lower than that under cultivation during one month. Otherwise, the moisture in the 12- to 24-inch and 24- to 36-inch layers was always greater under sod.

The greatest differences were at the 24- to 36-inch depth, which means that, on the average, the 24- to 36-inch layer under sod stores

annually the equivalent of a 1.2 inch rain. This may be available to the sod crop or to deeper roots of the following crop in the drier summer season.

Surface mulching in Pennsylvania resulted in maintaining an optimum soil-moisture content, even during the driest part of the growing season. Three and four years of mulching with manure, straw, sawdust, corn stover, oak leaves, or pine needles resulted in complete control of surface runoff. Soil under mulches had an infiltration capacity of 3 inches or more per hour. The chief value of mulch in controlling runoff and erosion was in its protective effect.

PLANT COVER INCREASED BY FERTILIZER

Adding fertilizer to the soil aids in reducing erosion losses because it produces more plant cover. The fertilizer stimulates early growth and hastens the date when the cover becomes effective. Fertilizer also increases the amount and density of cover by increasing total plant growth. Besides helping control erosion through the production of more vegetation, the use of fertilizer results in higher yields.

Two plots in Wisconsin were planted to a three-year crop rotation of corn, oats (these were fertilized in one plot), and hay. The average annual per-acre soil loss over a five-year period was 47.21 tons where no fertilizer was used, but it was only 13.13 tons per acre on the fertilized plot. Fertilizer reduced erosion better than 34 tons per acre annually.

In New York, use of 200 pounds of 5-10-5 fertilizer per acre annually on land planted continuously to corn reduced the loss of water by one-third and the loss of soil by two-fifths. This was the average of a nine-year period. Unfertilized corn land lost 9.5 per cent of the rainfall as runoff, and also 5,934 pounds of soil per acre annually. Fertilized land lost 6.4 per cent of the rainfall as runoff, and also 3,552 pounds of soil per acre.

Unfertilized Shelby silt loam in Missouri, planted to a three-year crop rotation of corn, wheat, and hay, lost an average of 8.81 tons of soil per acre annually during a seven-year period. Nearby land planted to the same rotation and fertilized lost 3.69 tons. Soil loss from land in wheat was reduced by one-half, and the loss from oats was reduced more than one-half. These reductions in loss of soil by erosion resulted from the increased cover obtained by the use of 200 pounds of fertilizer per acre. In addition, the fertilizer increased the wheat yield 91 per cent and the oat yield 77 per cent.

DIFFERENCE BETWEEN SOIL-DEPLETING AND SOIL-IMPROVING CROPS DUE TO PLANT COVER

Much has been said in recent years about soil-depleting and soil-conserving crops. Actually, the difference between the two kinds of crops is one of plant cover on the land. The soil-depleting crops do not provide enough cover, and they take less organic matter and minerals from the soil than the soil-conserving crops do. Cultivation and the habit of growth of the soil-depleting plants permit erosion; as a result, the total loss of nutrients from the soil is high.

Soil-conserving plants, on the other hand, provide good plant cover once they are established. Although these plants take more nutrients from the soil, they prevent losses through erosion and add organic matter to improve the soil's fertility. The comparative amounts of plant nutrients removed by crops in a five-year and three-year rotation, respectively, are shown in Tables 2 and 3.

TABLE 2

AVERAGE POUNDS PER ACRE OF PLANT NUTRIENTS REMOVED ANNUALLY BY THE GRAIN OF CORN AND OAT CROPS AND ALFALFA-BROME HAY IN A FIVE-YEAR ROTATION OF CORN, OATS, HAY, DURING A FOUR-YEAR PERIOD

Crop	*Calcium* (pounds)	*Phosphorus* (pounds)	*Nitrogen* (pounds)	*Potassium* (pounds)
Corn	0.35	9.46	52.55	10.86
Oats	2.01	7.36	42.82	8.92
Hay	42.90	13.52	109.31	103.43

TABLE 3

AVERAGE POUNDS PER ACRE OF PLANT NUTRIENTS REMOVED BY THE GRAIN OF CORN AND OATS AND BY HAY IN A THREE-YEAR ROTATION OF CORN, OATS, AND HAY

Crop	*Calcium* (pounds)	*Phosphorus* (pounds)	*Nitrogen* (pounds)	*Potassium* (pounds)
Corn	0.31	8.40	46.67	9.64
Oats	1.68	6.15	35.81	7.46
Hay	32.85	7.55	65.27	65.27

As previously stated, soil at Guthrie, Oklahoma, with a sod cover of Bermuda grass accumulated organic matter at the rate of 1,700 pounds per acre annually. In contrast, plots planted continuously to cotton during the same period lost the equivalent of all the organic matter returned as crop residues. In addition, they lost 1,860 of the original organic matter reserve each year. Table 4 gives the average

pounds of plant nutrients lost by erosion annually during a two-year period in Missouri.

TABLE 4

AVERAGE POUNDS OF PLANT NUTRIENTS IN ERODED MATERIAL REMOVED PER ACRE ANNUALLY DURING TWO-YEAR PERIOD

Treatment	*Nitrogen*	*Phosphorus*	*Potassium*	*Magnesium*	*Calcium*	*Sulphur*
	(pounds)	(pounds)	(pounds)	(pounds)	(pounds)	(pounds)
Continuous bluegrass	0.60	0.16	2.67	0.22	1.07	
Rotation Corn wheat clover	26.36	6.20	213.86	29.18	86.08	5.97
Continuous wheat	32.39	9.42	264.00	42.67	106.23	8.55
Continuous corn	65.90	18.00	605.30	87.29	220.84	16.66
Fallow	118.13	37.75	1,245.55	171.94	458.51	46.72

One of the most important benefits of plant cover is the preservation of this organic matter. It was generally believed that oxidation was responsible for the major losses of soil organic matter, but it is now known that soil erosion enjoys this distinction. Investigations in Missouri and Iowa showed the loss of soil organic matter by erosion to be twenty-five times as great as that by oxidation. Organic matter is the source of the soil's nitrogen, thus the loss of nitrogen in the organic matter removed by erosion is a controlling factor in crop yields.

This was illustrated by results from Clarinda, Iowa. In 1952, nitrogen was added at the rate of 180 pounds per acre to corn plots. These plots have grown corn continuously for the past twenty years, and the additional nitrogen eliminated the trouble that caused low yields.

Since 1932, corn has been grown continuously on one series of plots at Clarinda. It has also been grown in a three-year rotation of corn, oats, and meadow on another plot. The corn in each series received the same fertilizer treatment until 1952. The fertilizer treatment was the same again in 1952, except that the continuous corn plots received 180 pounds of nitrogen per acre, which the rotation plots did not get. The yields in 1952 were 103 bushels per acre on the continuous corn plots and 98.4 on the rotation plots.

These results show the effect of erosion on corn yields, as well as the effect of preventing erosion so that corn or other soil-depleting crops can be grown successfully year after year. Enough plant food and plant cover holds the key to this program. The heavy stalk production accompanying high corn yields should provide enough cover if properly utilized. Elimination of fertility losses by erosion

will plug the greatest drain on plant nutrients and will make soil building a relatively simple problem, either with or without crop rotation.

The average annual yields of corn in bushels per acre by five-year periods and for for both series of plots at Clarinda are given in Table 5.

TABLE 5

THE AVERAGE ANNUAL YIELD OF CORN IN BUSHELS PER ACRE BY FIVE-YEAR PERIODS, FOR FOR CORN GROWN CONTINUOUSLY, AND IN A THREE-YEAR ROTATION, INCLUSIVE

Cropping System	*Average Annual Yield in Bushels per Acre*				
Continuous corn	23.9	32.5	23.9	17.8	103.0
Rotation	25.8	57.0	72.0	83.9	98.4

* Includes the drought years 1934 and 1936 when the crop was a failure

Beginning with the second five-year period, the yield on the continuous corn plots declined from 32.5 bushels per acre to 17.8 for the fourth five-year period. During this time the yield on the rotation plots increased from 57 bushels per acre for the second five-year period to 83.9 for the fourth. The difference between the yields of these two plots, which became greater with time, was 1.9 bushels for the first five-year period, 24.5 for the second, 36.1 for the third, and 66.1 for the fourth.

Except for nitrogen, the figures presented in Table 2 do not show corn to be soil depleting in comparison with hay. The hay crop contained alfalfa, it is presumed, therefore, that the nitrogen removed in the harvested hay was approximately equal to the amount taken from the air by the crop. Thus, the original supply of nitrogen in the soil was not changed. However, the nitrogen removed by the corn crop was a net loss to the soil's supply.

Similar figures are given in Table 3 for the crops grown in a three-year crop rotation.

EXERCISES

1. Find an area in a pasture, meadow, or along some stream channel where the productivity of the soil varies widely. An abandonded field sometimes proves an excellent place for this study. Notice the change in the plants making up the ground cover at various locations. See if you can find any bare spots. If broomsedge or poverty grass appears,

examine the soil carefully to see how the topsoil has been removed by erosion. Also examine the soil for aggregates or tilth Notice that some form of plant cover is usually found on all sites regardless of the state of productivity of the soil This is Nature's way of building and holding soil

2. Select a sodded area on a gentle slope Stake out two small plots equal in area and remove the plant cover from one plot Observe what happens to the soil on this bared spot the first time it rains Compare with the adjoining area where the plant cover was not disturbed What differences do you notice? Also watch how soon new plants appear on this spot This is Nature's way of protecting the soil from wind and water and of restoring the soil-building process

3. Remove the litter from a small area on a forest floor Keep clean of falling litter for three or four months during the season of heavy rains What difference do you notice in the amount of erosion on this cleared spot and the adjoining areas where the litter was undisturbed? How do you account for the erosion on this cleared spot, since the foliage is still on the trees?

4. Why does it require a greater total weight of plant matter to control erosion with tall-growing crops, such as corn, cotton, and grain-producing sorghums than with close-growing crops, such as grasses and most clovers? To test this, take two plots, equal in area, of bare ground side by side Weigh the equivalent of 1,500 pounds per acre of straw or hay of some kind and of corn stalks, cotton stalks, or some other tall growing crop Scatter the residue of the close growing crop on one plot and that of the tall-growing crop on the other Observe the difference in the amount of erosion that occurs on these two plots after the first hard rain Why this difference?

5. Clean cultivated row crops, such as cotton corn and the grain sorghums, are referred to as soil depleting crops Likewise close growing crops, such as grasses and most clovers, are referred to as soil-improving crops Do these terms indicate the real nature of these crops? What are the chief differences between these two groups of crops, insofar as erosion and soil improvement are concerned

QUESTIONS

1. What are the two main functions of plants in building soil? How do plants perform these tasks?
2. How do we upset Nature's program when we put land in cultivation? How does this affect soil building?
3. What simple experiment showed that interception of raindrops was the main way plant cover prevented erosion? How did this same experiment show that flowing surface water was not the chief cause of soil erosion?

4. Are all crops equally effective in controlling raindrop splash? What simple test will show the effectiveness of different crops in intercepting raindrops?
5. How much cover per acre is needed with each of the three groups of crops? Why this difference? Why do all crops have about the same effectiveness up to 1,000 pounds per acre?
6. Why are close-growing crops more effective than others in controlling erosion?
7. What becomes of most of the organic matter and plant food removed from our soil? What can we do about this?
8. How does plant cover affect the amount of water that gets into the soil during rains? How does this affect the amount of water available for growing plants?
9. How does the use of fertilizer reduce the rate of erosion? How does erosion affect the efficiency of fertilizer? How is this accomplished?
10. What is the main benefit of crop rotations in a soil improvement program? How does this compare with our previous thinking?

11

Interrelationship of Land, Plants, and Animals

THE interdependence of plants and soils was discussed in the preceding chapter. Now we add animals to make this a threesome. We cannot properly manage our land or plants without giving attention to the equally important part played by animals

If we examine these relationships, we can see the interdependence of land, plants, and animals. Land furnishes food in the form of mineral elements for plants, but it also provides a growth medium—a place for plant roots to take hold. Plants, however, are equally important to the land, because they protect and aid in building soil.

A good plant cover completely protects soil from the erosive forces of wind and water. Decaying plants produce organic matter to increase the soil's ability to absorb water The same organic matter increases the fertility of the land and further improves the soil's ability to grow plants.

In a somewhat different way, land provides a place for animals to "take root." This is shown when they use the land for their burrows. Animals, in turn, exert an influence on the land. Witness the soil mixing and aeration accomplished by earthworms and burrowing animals. They also increase the organic matter and consequent fertility of the soil, by the decay of myriads of animal bodies—from the tiniest insects to the largest mammals.

The greatest contribution of land to animals, however, is indirect. It is through the plants, grown on the land, which furnish food and

cover for animals. Without plants, animals could not exist. But many plants would disappear were it not for animals. The pollination by insects and the seed distribution by many birds and mammals are examples. This relationship is being encouraged when a living fence is planted between cropland and pasture to provide a home for bumblebees, solitary bees, and other insects useful in pollinating red clover, sweetclover, alfalfa, and other legumes.

NATURE'S BALANCE

Plant and animal populations advance to a state of give-and-take adjustment referred to as Nature's balance. It is a dynamic balance, however, in that it is constantly changing as the productive capacity of the soil is altered. Soil is altered by the interaction of plants and animals, including man, living on it.

This "balance of Nature" is not confined to wild plants and wild animals. A system of farming that supports a family at a suitable standard of living without damaging the soil is in balance. It is as much in balance as are the plants and animals of a virgin forest. On

Figure 11-1. Streambank plantings control erosion, improve water conditions for fish, and provide food and cover for birds and other animals. These streambank plantings were photographed in Vermont. (Soil Conservation Service Photo)

the other hand, a system of farming that damages the soil is out of balance. A farm plagued with insects, weeds, and crop diseases is "out of balance with Nature."

Adjustments to making proper use of the land can do much to make a farm biologically (living things) balanced. For example, grazing woodlands upset the biological balance. Grazing woodlands in northwestern Ohio reduced insect-eating shrews to less than half the number in ungrazed and protected woods. Shrews are small, short-tailed, mole-like animals that maintain numerous path-like runways in the loose, upper layer of forest soil. These runways, which are used by the shrews in their search for food, help to aerate and incorporate organic matter into the soil. The runways also serve as reservoirs for water. Heavy grazing destroys these runways, because the trampling of animals packs the soil so that the shrews cannot re-establish them.

Strip cropping brings an increase in ground-nesting birds. A study by the Soil Conservation Service in southwestern Ohio showed how this increase occurred. The effect of strip cropping on ground-nesting birds was as follows

AVERAGE NUMBER OF PAIRS OF BREEDING BIRDS
PER 100 ACRES OF CROPLAND

Crop	*Open Fields*	*Strip-Cropped Fields*
Corn	3	4
Small grain	10	27
Meadow	48	93

Living fences provide homes for such insect-eating birds as brown thrashers, catbirds, and cardinals. They also protect predaceous insects, like lady beetles, assassin bugs, and damsel bugs; field shelter belts do the same thing.

Streambank planting aids in the control of bank erosion, because it improves conditions for fish by shading and cooling the water. At the same time, game birds, songbirds, and furbearing animals find cover there.

Biologic balance is also aided in the management of farm ponds for fish production. This involves what is known as a "food chain." The chain begins with water and mineral elements, which are necessary for the production of microscopic plants known as algae. Small crustaceans (shellfish) and insect larvae feed on the algae. Collectively, these small animals and plants are known as plankton. Plank-

ton is the chief source of food for bluegill sunfish, which are in turn fed upon by largemouthed black bass. Both the sunfish and the bass are used as food by man.

Bluegill sunfish reproduce very rapidly. If there are no largemouthed bass present, the bluegill sunfish get out of hand and become so numerous that there is not enough plankton to feed them properly. The result is a stunted population of bluegills, and the pond is "out of balance." We cannot harvest fish of sufficient size to use for food.

An odd area can be made to contribute to the biologic balance on the farm. The area may be a bare knob, blow-out, sinkhole or small odd-shaped area isolated by a gully or stream. The farm that keeps all natural nooks intact will come nearest to attaining the biologic balance so necessary to wild creatures. It will produce wildlife food and cover as widely distributed and abundant as can be compatible with successful farming. It also uses all the aid Nature can give for maintenance of the farm.

ECOLOGY

The principles of ecology are basic to sound land management. They deal with the effect of the total environment (soil, climate, man, and so forth) on plants and animals—this includes the effect of plants and animals on the environment as well.

Communities. Plants and animals do not live alone, but in definite communities, or mixtures. Some of the many factors that determine what species (kinds) of plants and animals will be found in any given community are soil, climate, physiography, and biota. "Biota" means simply all the plants and animals of a community and their effect on each other and on the site.

The importance of soils in determining the composition of any community can be illustrated by the growth of alfalfa on limestone soils and its failure to grow on acid soils. Similarly, pheasants, for some reason yet unknown, thrive in areas of glaciated soils but do poorly in loessial or residual soil areas.

Climate exerts its influence on plant and animal communities largely through length of growing season and rainfall, but even the length of daylight has its effect. Red clover, for example, thrives best where the day is long, while tobacco does best with a short day. Climatic factors also govern the migration, hibernation, and breeding of animals.

Northern slopes support plants and animals that are different from those on southern slopes. In prairie areas, trees are restricted to river valleys and moist slopes bordering drainages.

Effects of the biota may be less noticeable than effects of the factors discussed above, but they are just as important. In most cases, communities are mixtures of plants and animals. When a farmer attempts to grow a forty-acre "community" of a single species, such as corn, he is beset with competition from weeds. But when he attempts to grow an integrated community, like alfalfa and bromegrass, he gets better results. These plants complement, rather than compete with, each other.

Certain plants and animals are dominant in any natural community; others take a lesser place, or are subdominant. The result is a "layering" of plants, as in the forest. In the forest, small herbaceous plants are dominated by shrubs, which are in turn dominated by young trees beneath a canopy of truly dominant large trees. There is a similar stratification of animals, except that animals living in the larger trees do not necessarily dominate those living on the ground. Myriads of animals, mostly insects, live in the ground near the surface. Many birds (and cottontail rabbits) live on the ground, whereas others like to nest in the tops of tall trees. Some birds and animals, such as woodpeckers and squirrels, live in dens.

Succession. Communities constantly change as various factors modify the environment. This process is known as "succession." Succession of animal communities usually follows succession of plant communities. For example, the birds of a prairie area are ground-nesting birds, but as shrubs invade the prairie, or are planted there, species of birds that nest in shrubs follow.

Succession ordinarily starts with bare soil or water. Early occupants of bare soil are aggressive annuals, such as foxtail, ragweed, or poverty grass. Their growth improves the environment so that short-lived perennials, like yarrow, goldenrod, or fleabane, can take over. Succession depends on available moisture, seed sources, and other factors. The area may next be invaded by more useful plants, such as Kentucky bluegrass, native prairie grasses (bluestem, for example), or shrubs like hazelbrush, sumac, or buckbrush.

Succession stopped with the native prairie grasses in the prairie areas. In other areas, the shrubs improved the environment so that such pioneer trees as bur oak, aspen, jack pine, or red cedar became established. In some cases, the succession stopped with an oak-hickory community.

Succession goes forward naturally to a climax community, unless stopped by some outside influence. A forest fire can set back what was a maple-basswood climax forest to the shrub stage. Plowing returns a plant community to the bare soil stage, but the soil may be more fertile than it was in the earliest stages of succession.

Starting with a bare water area, such as a farm pond, succession begins with submerged vegetation like algae and pondweeds. Floating vegetation, such as water lilies, soon invades the pond and shade out submerged plants. As the accumulation of dead plants and silt is built up in the pond, the reed-marsh stage is reached. At this stage plants like cattail and bulrush predominate. Further accumulations make conditions favorable for sedges, rushes, and spike rushes.

When the pond is nearly full of decayed plants and silt, willows and cottonwoods are able to take root, and are later replaced by elm, soft maple, ash, and walnut. Lowland prairie grasses, and later upland prairie grasses, replace the sedges, rushes, and spike rushes in a climate favorable to prairie.

The water succession, like that on land, can be speeded up, stopped, or set back by outside influences. By managing a farm

Figure 11-2 Bicolor lespedeza border to the right and sericea lespedeza strip next to the corn. Both lespedezas are prolific seed producers. This arrangement provides excellent cover and food for wildlife in Alabama.
(Soil Conservation Service Photo)

pond to exclude floating and swampy vegetation, it can be kept in the submerged vegetation state indefinitely. Drainage and silting can change the course of succession rapidly.

Ecotones. An ecotone is the area where two different plant communities meet. It is, for example, where prairie meets woodland, a cornfield meets a hayfield, or cropland is adjacent to woodland. The ecotone, or edge, is more productive of wildlife than either of the two communities that go to make it up.

This can be illustrated with the habits of pheasants. Pheasants like to eat corn, but a cornfield is a poor place to roost at night—a hedge or cattail marsh with dense cover is much better. Therefore, the pheasant must find a place where both corn and thick cover are close together. Places where these cover types adjoin or overlap will be most used by the pheasants.

ECOLOGICAL PRINCIPLES APPLIED TO SOIL MANAGEMENT

Plant indicators. Soil surveyors have long made use of ecological principles. They did this when they used native vegetation as an indicator of the type of soil. The presence of sedges and rushes usually indicates a tight, poorly drained soil. Poverty grass, reindeer moss and sheep sorrel usually indicate acidic soils. In the present day landscape, sweetclover indicates a *p*H (degree of acidity) above 6.3.

Native legumes frequently indicate droughty, depleted sites. Broomsedge is a good indicator of poor land management rather than of inherently poor soil. The absence of trees in a long-abandoned field indicates the site is not capable of supporting trees native to the vicinity. The presence of mullein, yarrow, or vervain indicates an overgrazed pasture. On the bluffs along the Mississippi River, overgrazing is resulting in an invasion of red cedar. In other areas, thorn apple follows too many cattle.

Relation to land-capability classification. We are really using applied ecology in the land-capability classification. We do this when we say, in effect, that land in Classes I, II, and III is such that environmental conditions can be kept in the early stages of plant succession. That is, it can be kept in annual and a few herbaceous perennial plants, without damaging the environment. In the case of Class IV, we recognize the land must be kept in herbaceous perennials, with occasional annual crops, to prevent it from eroding.

Class V land must be kept in herbaceous or woody perennials, because the environment is not suited to the growth of annual plants. Classes VI and VII must be kept in perennial plants to preserve the land's present productive capacity. Class VIII land calls for treatment with vigorous, hardy pioneer plants. Plants can be established on sites usually incapable of supporting plants high in the successional scale.

Cropland. Farmers apply ecological principles when they plant, by plowing, seeding, and cultivating, to keep cropland in the initial stages of plant succession. They grow annual or biennial crops like corn, small grain, cotton, or soybeans. The same is true when lime and fertilizer are applied. This permits the growth of plants that could not otherwise grow on land that is acidic or of low fertility. Mulching is another practice that modifies the environment to improve conditions for desired plants.

Pasture land. On pasture land, renovation and clipping of weeds are examples of applied ecology So is the cutting of brush and weeds at a time of year when their vitality is the lowest. The introduction of legumes that are compatible with adapted grasses actually improves the stand and quality of the grasses. Regulation of grazing to maintain the desired combination of legumes and grasses also involves a knowledge of ecological principles.

Woodland. Principles of ecology are constantly used in woodland management. When trees are to be planted, a species adapted to the environmental conditions must be selected if satisfactory results are to be expected Protection from fire and grazing are important, because this allows the woodlot to progress normally toward its climax. Improvement of harvest cuttings must be guided by a knowledge of ecology if certain desired species of trees are to be favored. For example, it is now known that strict selective cutting in an oak-hickory woods will, in most areas, result in a maple-basswood climax.

If oak reproduction is desired, cuttings must be made in larger blocks to allow sufficient sunlight for oak reproduction and growth. Shrub borders around woodlands are recommended, for they reduce the effect of drying winds and help maintain a desirable leaf mulch out to the edge of the woods. They also affect the moisture relationships within the woods to the benefit of the trees. Leaving den trees in a cutting operation is a means of keeping several tree planters (squirrels) busy working on each acre.

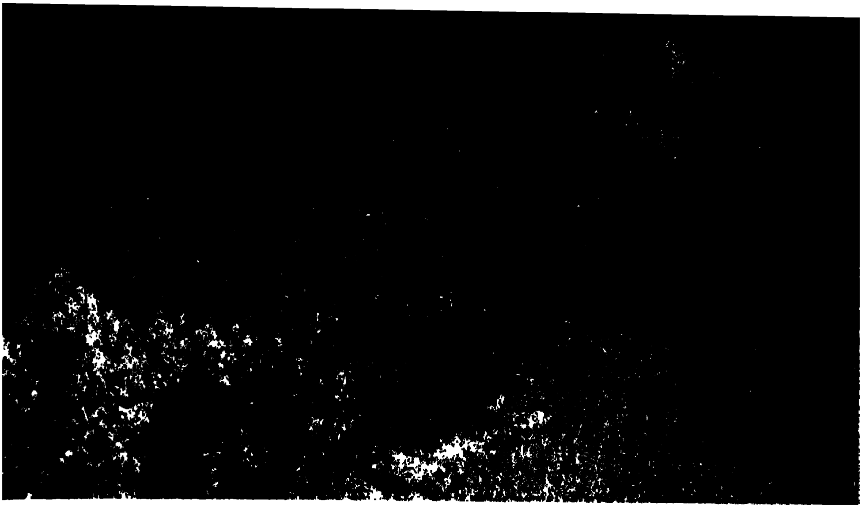


Figure 11-3. Buffer strips of fruit-bearing shrubs provide both cover and food for wild animals in North Dakota. They also make the food in the cultivated portion of the field more accessible. (Soil Conservation Service Photo)

Wildlife land. There are many examples of the application of ecological principles in the management of wildlife land. In drainage-ditch bank management, species of grass capable of growing on subsoil must be used. Even then, their growth frequently hinges on adequate soil treatment. These plants should be capable of withstanding flooding, be sod-forming to control erosion, and be able to compete with willows and cottonwoods. Willows and cottonwoods are undesirable because they reduce the capacity of the ditch. The grasses should also furnish food and cover for muskrats.

Fence-row management. Fence-row management illustrates a variety of ecological principles. When we plant a living fence between cropland and pasture, we create a new environment that favors insect-eating birds that like to nest three to six feet off the ground. We also add an ecotone, or edge, that can be used by game birds and fur-bearing animals. We develop a home for pollinating insects. When we refrain from burning a fence row, we are well on the road to the solution of fence-row weed problems. If not burned, the weeds will eventually be replaced by perennial grasses and shrubs. Repeated burning keeps the fence row in the annual seed stage of plant succession.

Pond management includes the control of marsh plants in shallow water. Marsh plants furnish hiding places for small bluegill sunfish

from bass, and in addition, are part of the next stage in the water area succession. Their presence may shorten the life of the pond. Management of odd areas involves the use of ecological principles, by the selection of plants suitable to the wide variety of soil conditions encountered throughout the country

Marsh management makes use of at least two ecological principles Control of water levels provide optimum conditions for the growth of aquatic plants, which insures an adequate food supply for muskrats Level ditching is designed to alter the environment by increasing the area of open water, which makes the habitat more desirable for muskrats

Streambank management, if applied to a sufficient length of stream, benefits fish, reduces the silt content of the water through the control of erosion, and cools the water by shading Streambank management also provides an ecotone useful to birds and mammals

IMPORTANCE OF WILDLIFE TO AGRICULTURE

Wildlife borders make their chief biological contribution through the ecotones they create Most forms of wildlife help farmers produce more and better crops, by checking insects, weeds, and other pests The number of beneficial forms of wildlife a well managed

Figure 11-1 *Multiflora rose fence in South Carolina In addition to serving as a fence, it provides excellent cover The plants have an ultimate spread and height of about eight to ten feet* (Soil Conservation Service Photo)

farm supports is surprising. If it were not so great, pest problems would be much more serious than they are. By assuming that a 100-acre farm had about one-third of its fence rows in woody cover, and that the farm had 15 acres of protected woods, 25 acres of good pasture, and the remaining 60 acres in a four-year crop rotation (the crop rotation includes two years of meadow), we were able to estimate that the beneficial wildlife population would be somewhat as follows:

1. Several million beneficial insects, such as lady beetles, aphis lions, and syrphid flies which feed on plant lice; chalcid flies and tachinid flies which parasitize many kinds of insects; and assassin bugs, ambush bugs, robber flies, and nabids which capture and feed on other insects.
2. More than forty kinds of beneficial birds represented by over 400 individuals: eighty of these would be associated with the fence rows, 180 with the woods, ninety with the meadow, nine with small grain, and three with the corn.
3. More than a thousand beneficial small mammals, principally short-tailed shrews; about 40 percent of these would be in the meadow, 30 percent in the pasture, 20 percent in the woods, and the remaining 10 percent in the fence rows, grain, and cornfields. Of the twenty or more kinds of small mammals commonly found in the neighborhood, at least ten probably occur on every farm.

Game birds and animals provide farmers and their friends with sport and food. Farmers having ponds and lakes or streams also get much pleasure and food from fish. Furbearing animals furnish recreation and cash income.

Another important value of wildlife is found in the pollination of many plants, particularly legumes, by honeybees, wild bees, and other insects. Studies in Ohio and some of the Western States showed that with sufficient insect pollination, seed yields of alfalfa, red clover, and alsike clover can be increased as much as fourfold. Living fences, wildlife borders, and streambank management increases the amount of favorable environment for pollinating insects.

Some forms of wildlife, particularly some insects and mammals, are detrimental to agriculture. When overabundant, they may become harmful. One of the ways to control species that are harmful is to do those things that encourage their natural enemies. The

establishment of living fences, for example, encourages birds that help to control insect pests.

Birds. The food habits of birds make them especially valuable to agriculture. According to U.S. Department of Agriculture estimates, birds destroy harmful insects to the extent that $350,000,000 in crops is saved each year. The total loss to agriculture from insects is considered to be $700,000,000 annually. By increasing the present number of birds through good land use and soil management practices, the usefulness of birds as insect destroyers can be materially increased.

Birds require huge amounts of food. They have higher body temperatures, more rapid digestion, and expend more energy than most other animals. They usually consume as much or more than their own weight in soft-bodied insects every day. Young robins have been known to gain eight times their original weight in the first eight days of their life.

Insect-eating birds must fill their stomachs five or six times daily. Their digestion is rapid and much of the insect food is indigestible. A young robin, in captivity, that weighed three ounces consumed 165 cutworms weighing 5½ ounces. If a ten-pound baby ate at the same rate, it would have to eat 18⅓ pounds of food in one day.

Although birds are of great value to agriculture, they cannot keep weeds and insects under control. Present populations of insect-eating birds could probably be doubled if every farmer did all the practical things he could to encourage them. Even so, from time to time he still would have to use other measures of insect control. Some birds are also valuable as enemies of mice, rats, gophers, and the like.

Mammals. Production of furs and control of small rodents are probably the most important contributions of wild animals to agriculture.

At least six species of wild animals are effective in reducing the numbers of such harmful rodents as mice, rats, and rabbits. At least five species are active insect destroyers.

Many species of small mammals feed extensively on insects. In field borders and woodlands their populations commonly run from 100 to 300 per acre. Small mammals feed throughout the year while most birds migrate in winter; as a result, there are more than 32,000 insect-eating mammal-days per acre of shrub border, compared with about 13,000 bird-days per acre. It has been estimated that a hundred

small mammals could consume 266 pounds of insects per year. If we figure 10,000 insects per pound, that would be 2,660,000 a year.

Deer, rabbits, squirrels—and sometimes opossum, raccoon, muskrat, and woodchuck—are used by man for food.

Squirrels probably planted all the hickory trees in the United States, as well as many of the oaks, walnuts, and butternuts. Despite accelerated tree planting by farmers, squirrels are still planting more trees than man. If seed trees are nearby, squirrels will establish a forest on many acres after the land has been protected from fire and grazing.

Fish. The chief values of fish are for sport and food. In particular fish may be an important source of food on the farm. It has been shown that from 150 to 250 pounds of fish per acre can be removed from ponds and small lakes each year if they are carefully managed. Thousands of miles of streams and rivers are also producing large amounts of fish. Such production on land that is hardly suitable for any other use is important.

MAIN REQUIREMENTS OF WILDLIFE

To be suitable for wildlife, a farm must provide food, cover, and water. These must be distributed in such a way that all are available within the distance birds and animals travel in one day.

Actually, the more places developed on a farm where food, cover, and water are close together, the greater the wildlife population it will support. However, development of cover or water any place on the farm is beneficial to some forms of wildlife.

Food. A large part of the farm land is devoted to the growing of corn, small grains, and legumes. Modern harvesting methods leave a good deal of waste grain in the field, in many places, wild fruits and weed seeds are common. Thus, the amount of wildlife food produced may be adequate, but because much of it is far from cover, or may be covered by snow and ice, its availability when needed is often a problem.

Wildlife food is usually adequate in late spring when insects become abundant; in the summer, when insects, wild fruits, and green plants are available; and in the fall, when insects, wild fruits, weed seeds, nuts, waste grain, and green plants can all be had. The critical season is winter when there are no insects, wild fruits are gone, and snow and ice cover waste grains. At the same time, the amount of

cover diminishes, and some food becomes unavailable because it is too far from suitable cover. Early spring is often just as critical a period.

The planting of perennial food-producing plants close to cover is one way to insure available food supplies throughout the year. Some of the best plants for this purpose are bicolor lespedeza, sericea lespedeza, and multiflora rose.

Another way to make food available, and the only practical way for the northern part of the country, is to extend cover closer to natural food sources.

Cover. Any animal, in order to exist on an area, must have cover that will provide concealment for nest and young, shade from the hot sun, and shelter from chilling rains. It also must provide escape routes and protection from cold, wind, sleet, and snow.

If located close to food and water, most cover in many sections of the country is adequate during late spring, summer, and fall. The critical season is the winter and early spring. The planting of locally adapted conifers close to sources of food and water is highly recommended. At least one clump of twenty to fifty conifers or other adaptable trees should be included in every tree-planting area. Safe nesting cover for ground nesting is often inadequate because of burning or mowing operations. A few areas that are never burned and are not mowed until after the nesting season should be provided on every farm.

Water. All kinds of wildlife require water. They obtain it from one of the following sources:

1. Ponds, streams, springs, drainage ditches, tile outlets, marshes, and lakes or snows.
2. Food of high moisture content, such as fruits, succulent leaves and sprouts, juicy insects and their eggs.
3. Dew.

Most upland wildlife can survive on water from succulent foods and dew, but the highest populations can be maintained where surface water is available. Surface water will make possible a greater variety of wildlife because water-loving species, such as red-wing blackbirds, muskrats, raccoons, and others, will be attracted to it.

The use of land for wildlife production does not necessarily require a definite area to be set aside for the purpose. Wildlife is a secondary crop on lands used for growing grain and hay, for pasture, or for woodland. It is a primary crop only on wildlife land.

RELATIONSHIP OF FOOD, COVER, AND WATER

To be suitable for wildlife a farm must provide food, cover, and water, distributed in such a way that all are available within the distance birds and animals will travel in one day.

These distances are not known for all forms of farm wildlife. A few for which the information is available are given below

Wildlife	*Distance* (miles)
Muskrat	1/10 to 1/2
Partridge, Hungarian	1/8 to 1/[illegible]
Pheasant, ring-necked	1/2 to 1
Quail, bobwhite	1/8 to 1

These are seasonal averages The daily limit of travel will usually be no greater than the shorter distance given above

The following is information also available on the home range of a few species

Wildlife	*Home Range* (acres)
Grouse, ruffled	40
Mouse, field	1/1[illegible] to 1
Mouse, prairie deer	1/[illegible] to 1
Opossum	11 to 40
Rabbit	3 to 8
Shrew, short tailed	1/[illegible] to 1
Squirrel, fox	10 to 40
Woodchuck	40 to 160

It is clear from these figures that farm wildlife species occupy relatively small areas The abundance of wildlife can be increased when suitable habitat is well distributed over the entire farm Probably a combination of one permanent cover area close to food for each 20 acres of land would be ideal Land conditions vary so widely, however, that such ideal conditions will occur on relatively few farms.

EXERCISES

1. Draw a sketch of a real farm Show location of woods fields, and of wildlife food, water, and cover areas Draw a second sketch of the same farm. Show changes you would suggest for improvement of wildlife conditions

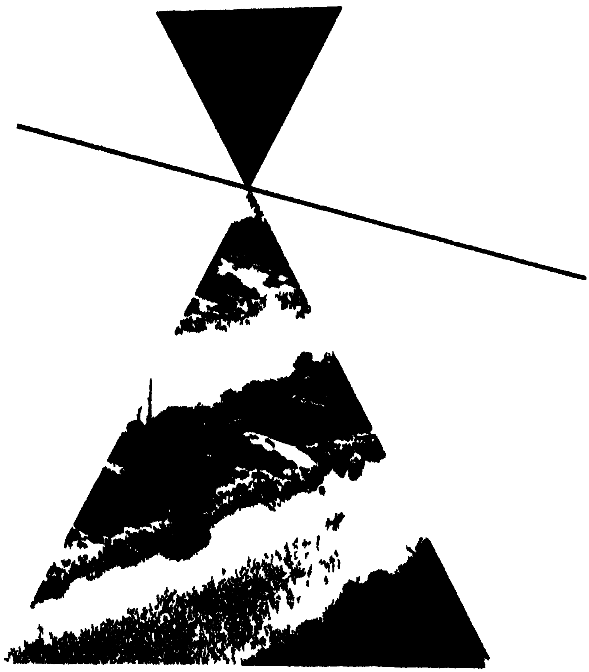
2. Make a study of wildlife communities in cultivated fields, the woods, and pastures. Make a list of the animals you find in each area. Compare these lists to see how the environment affects the types of animals in each of the three communities.

Questions

1. Why is it necessary for us to know the relationship between animals and the soil and plants? How are animals dependent upon the land and plants?
2. What do we mean by biological balance? How does it apply to an individual farm?
3. What is meant by Nature's balance? How does man enter into it?
4. What is a community? What three elements make a community?
5. What do we mean by succession? What relation is there between succession and the soil and water?
6. What is the chief importance of ecotones or edges?
7. What is the principal crop on wildlife land? What is the best way to get rid of weeds in the fence row?
8. How does wildlife aid the farmer?
9. What are the main requirements of a wildlife program?

Part III

SOIL CONSERVATION PRACTICES



12

Erosion Reduces Productivity

We know now that erosion is the most widespread and destructive agent of our soil. Erosion destroys the productive capacity of cultivated land faster than all other factors combined and removes the organic matter, nitrogen, and clay and silt particles. These are the life of the soil. In extreme cases erosion removes the physical soil body itself.

Erosion also reduces the available water supply in two ways: (1) by reducing the amount of water storage space and (2) by making it more difficult for the soil to absorb water. Erosion reduces the amount of water storage space by removing part of the soil. Because of this, much of the storage space and depth of topsoil are reduced. Also, the amount of water absorbed by soil through puddling the surface of the soil is reduced. Water can't get into the ground easily.

In their mildest forms, water and wind remove only organic matter and silt and clay from the plant food bearing portion of the soil. In this case, we experience no great loss of soil, but our soil is left less fertile, and will not grow as good crops. To restore such soils to their original state of fertility, the plant nutrients and organic matter removed must be replaced. Even if this were possible to do, it would be expensive. In many cases, replacing the lost material would be out of the question.

In their most violent forms, wind and water remove our plant food—soil and all. Usually the soil is removed in sheets, although in some cases, it may be gouged out in gullies. In other cases, a portion

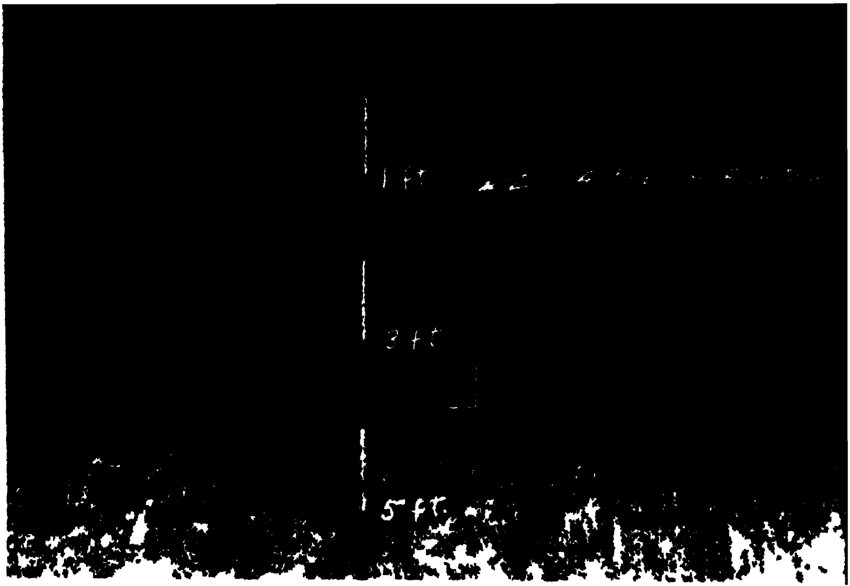


Figure 12-1 At the top of the topsoil layer Nature brings to bear the full effects of all forces that contribute to the development of soil The rocks are broken into fine fragments and the growing plants supply the organic matter that changes the rock mass into soil The top layer of this topsoil is the most productive part of the soil body The first soil removed by erosion comes from this top layer The A horizon (black layer) on this Texas Houston clay is approximately four feet thick (Soil Conservation Service Photo)

of the topsoil layer is removed, which reduces the feeding area of plant roots, as well as the amount of moisture and food available for plants It also means lower crop yields and less food for us We use the same amount of time and effort in cultivating an acre of this soil as we do in cultivating undamaged soil, but we get lower crop yields as our reward

PROGRESS BLOCKED BY EROSION

Erosion has canceled most of our gains from improved methods of soil and crop management We have made many improvements in agriculture during the last sixty to seventy-five years and have developed better-adapted and higher yielding varieties of crops We have used better machinery to till our soils, improved the quality of our fertilizer, and increased by many fold the amount of fertilizer used We have used better insecticides and improved our methods of controlling plant diseases We made many other improvements, too

Had we protected our soil from water and wind, its fertility would have remained high, and our yields would have more than doubled. Actually, gains in yields until recent years were small—with some crops, no increases occurred. Water erosion carried away our soil fertility and canceled effects of improvements made in agricultural methods. Our crop yields remained practically unchanged. For example, our average yields of cotton and corn varied little from 1869 to 1938, but after 1938, yields in part of our crops

Figure 12-2 *As the surface soil is eroded away the feeding range for plant roots becomes restricted. This Missouri field of Shelby silt loam has lost more than two thirds of its original twelve inches of rich topsoil. The eroded soil can never be made to produce as high yields as the virgin soil as long as it receives similar treatment.* (Soil Conservation Service Photo)

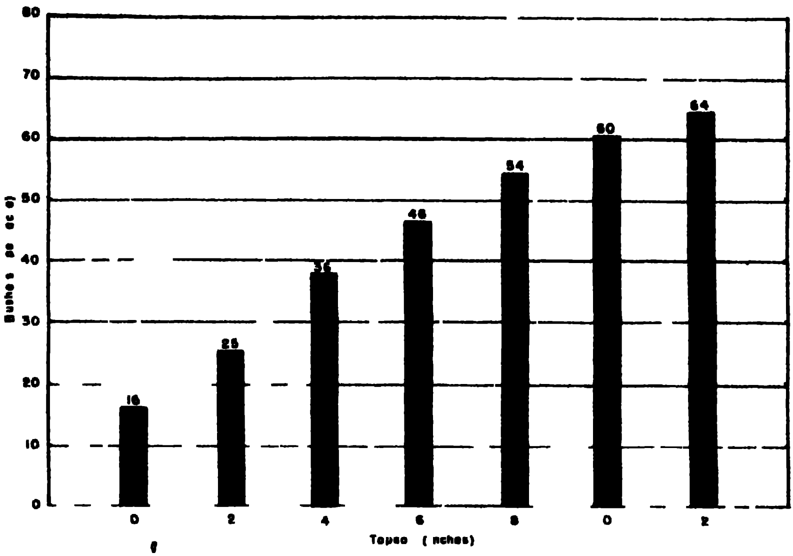


Figure 12-3 As the fertile topsoil is removed by erosion the crop productive capacity of the remaining soil is reduced. This is shown by average annual yields of corn in bushels per acre on Shelby, Grundy and Mexico soils in Missouri as influenced by the depth of topsoil

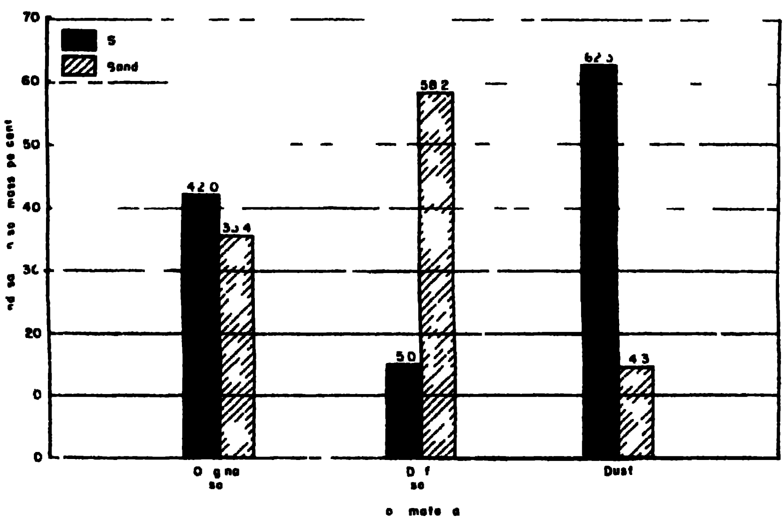


Figure 12-4 Changes in silt and sand content of Richfield silt loam caused by the sifting and sorting action of wind in the erosion process

rose. This rise in crop yields was due in part to the spread of conservation practices, which included better erosion control, use of more fertilizer, and improvement of other practices.

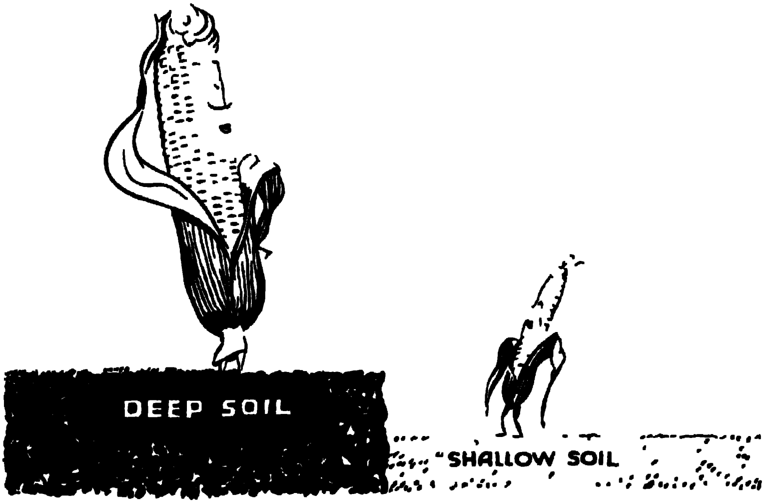
TABLE 6

NATIONAL AVERAGE ANNUAL ACRE YIELD OF COTTON AND CORN BY TEN YEAR PERIODS BEGINNING WITH 1869 AND ENDING WITH

Year	*Average Annual Acre Yield*	
	Cotton Lint (pounds)	*Corn* (bushels)
1869-78	171.6	25.9
1879-88	172.5	25.8
1889-98	191.[illegible]	26.0
1899-08	18[illegible]	27.4
1909-18	1[illegible]3.3	25.8

* Average for the nine year period, ending with

Figure 12-5. The two ears of corn graphically represent the relative productive capacity of the virgin and eroded Shelby silt loam shown in Figure 12-2. This relationship in productivity will continue indefinitely, provided the two areas are given similar treatment. (Soil Conservation Service Photo)



Erosion destroys soil fertility. The extent to which erosion reduces the fertility of our soil is not fully known or appreciated, because wind and water sort out the lighter fertility-bearing particles first. By the time erosion becomes noticeable, much of our soil fertility is gone. We now know erosion removes several times as much plant food from our soil as growing plants take.

This may be illustrated by what happened, in Alabama, to a field of sandy soil. It was so nearly level we didn't think it was eroding, so it was very surprising to find it had lost, through erosion, 60 per cent of all the phosphoric acid applied to the crops grown on it during a twenty-six-year period. During the same period, 82 per cent of the phosphoric acid applied in rock phosphate was removed by erosion. To make matters worse, a three-year crop rotation was used during the whole period. We thought crop rotations improved our soils; they mainly lower the rate of loss of plant food by erosion.

The phosphoric acid was carried away in the clay, which was floated off the field by surface flow. The soil contained only 6 per cent of clay, yet the clay held over 50 per cent of the soil's supply of phosphoric acid.

ACCUMULATION OF ORGANIC MATTER PREVENTED BY EROSION

We know it is practically impossible to keep lots of organic matter in our soil. We haven't been able to keep the organic matter content of our soil from declining; we have tried to increase it but have failed. We thought that our organic matter was being destroyed by soil organisms or microscopic plants and that these organisms used the organic matter as food and broke it down to oxygen and other gases in what we call oxidation (burning). We consoled ourselves by saying our trouble was a high rate of oxidation of our organic matter.

When we found we had been mistaken about how our soils erode, some of us wondered if we were not mistaken about soil organic matter, too. We wondered if our organic matter got out of the soil as we thought it did, so we decided to take a look at our organic matter problem to see what actually happened to it.

We found organic matter was the first thing wind and water removed from our soils. When we learned this, we got an idea. We thought maybe our organic matter was going out our back door

and we didn't know it. So we made some tests. Again, we made tests in the laboratory and in the field.

At first, we didn't believe what we found, so we made more tests and got the same results: We found wind and water removed most of the organic matter from our soils. In Missouri and Iowa, we found erosion removed organic matter from our soils more than twenty-five times as fast as oxidation, or the method we supposed removed it.

We found wind removed organic matter from our soils where soil erodes by wind and that water removed it where water erosion is active. Raindrops splashed it up, and flowing water swept it out of the field.

We also found that the rate we lost organic matter from our fields depended on the amount of plant cover we kept on our land. Land in cotton or corn lost lots of organic matter. Lands in grass and clover or sod crops didn't lose any organic matter; they actually increased their organic matter content.

For example, we found a plot of land at Guthrie, Oklahoma, planted to Bermuda grass gained 1,700 pounds of organic matter annually. An adjoining plot planted to cotton lost organic matter equivalent to all organic matter returned as crop residues. In addition, it lost 1,860 pounds annually of the organic matter in the soil at the time the study started. Another plot cropped to a three-year rotation lost all the crop residues returned, as well as 940 pounds of its original supply of organic matter each year. This study covered a ten-year period.

During this same period, continuous cotton plots lost by erosion an average of 18.9 tons of soil per acre annually. The rotation plots lost 4.2 tons of soil and the Bermuda grass plots 0.02 ton annually.

Topsoil is most fertile. The top layer, or topsoil, is the most productive part of our soil, and it is there that Nature used all her forces developing soil. Rocks from which all soil is derived (except peat and muck) were more completely disintegrated and decayed at the surface than at lower depths. Plant life developed at the surface and played an important part in changing rock to soil. It also added organic matter, which makes the difference between soil and rotten rock.

Remains of growing plants were mixed with the decomposing rock, which supplied the organic matter to make soil productive. The continual process of adding organic matter and disintegrating rock resulted in productive soil at the top, or topsoil. With time, the

soil-building process changed more of the rock mass into soil to make the topsoil layer deeper. But at all times the top layer remained the most productive. Here, the rock was more completely disintegrated and contained larger amounts of organic matter.

It is natural, then, for erosion to remove our most productive soil first. In other words, erosion removes the soil in the same order in which it was developed - from the top down.

Erosion reduces productivity. Virgin soil—never cultivated—was the most productive Nature could develop under the climatic conditions existing. Any tinkering we do with virgin soil changes its condition- usually for the worse. By changing either the depth, structure, organic matter content, or other characteristics, we alter its productivity. When we upset Nature's balance of factors making up the soil's productivity, we reduce its crop production power.

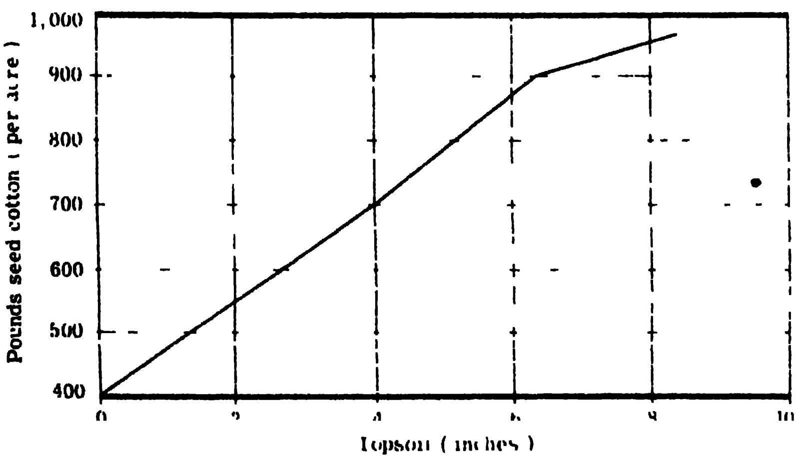


Figure 12-6. Relation between depth of topsoil and cotton yield on Cecil soil at Watkinsville, Georgia.

THE DECREASE OF TOPSOIL PRODUCTIVITY FROM TOP DOWNWARD

Suppose the environment under which soil was developed permitted the development of a topsoil twelve inches in depth. The loss of any part of this affects its productivity. If an inch of this topsoil is removed by erosion, the remaining eleven inches will produce

less than the twelve-inch layer. Should an additional inch of soil be removed, leaving only ten inches, it will produce even smaller yields.

If conditions under which soil developed required twelve inches of topsoil for maximum plant production, the loss of any part of it would reduce crop yields. This loss is permanent, and can never be regained.

TABLE 7

EFFECT OF DEPTH OF TOPSOIL ON YIELD OF CORN

Depth of Topsoil (inches)	*Bushels per Acre*			
	Indiana	*Iowa*	*Missouri*	*Ohio*
0	19	...	16	...
2	32	56	25	...
4	41	69	38	33.7
6	48	83	46	46.4
8	54	97	54	51.1
9	. .	...	...	59.5
10	58	102	60	...
12	64	125	64	.
13	67	...	...	...

The soil remaining may be brought to a high state of productivity by the use of fertilizer and other good soil management practices. But, it can never be made to produce as much as the original uneroded soil if given similar treatment.

TABLE 8

EFFECT OF ADDITION OF FOUR TONS OF MANURE PER ACRE ON THE YIELD OF SEED COTTON ON A, B, AND C HORIZONS OF CECIL SOIL

*Horizon**	*Yield of Seed Cotton per Acre*	
	Unmanured (pounds)	*Manured* (pounds)
A	561	845
B	348	501
C	51	42[illegible]

* Soil horizon is a layer of soil approximately parallel with the land surface. Horizons have distinctive characteristics. These were produced in the soil-building processes. The A horizon is the upper part and contains the most organic matter. It is usually dark in color. The B horizon lies under the A and consists of weathered material. It has an accumulation of clay, iron, or aluminum. The C horizon, under the B, is the layer of unconsolidated, weathered parent material.

REMOVAL OF MOST PRODUCTIVE PART OF SOIL BY WIND

The wind sorts out the organic matter and lightweight silt and clay particles and blows them away. The first dust storms are the

most damaging. At this time, the soil contains the largest amounts of plant-food-bearing silt and clay. More of these materials are removed with each succeeding dust storm, but the sand and other coarse materials are left behind. The organic matter and silt and clay are the most important parts of the soil, because they supply the food needed by the plants. As this food supply is reduced, crop production declines.

Samples of dust collected in Oklahoma during the dust storms of the 1930's contained, on the average, 62.5 per cent silt and 14.3 per cent sand. The original soil contained 42 per cent silt and 35.4 per cent sand. Soil in drifts contained only 15 per cent silt and 58.2 per cent sand. In other words, the percentage of material suitable for plant food was about twice as high in dust deposits in buildings as it was in the soil from which the dust came.

After a dust storm in Kansas in 1948, both the drift and eroding soil contained much less organic matter than similar soil in non-eroded fields. Much of the organic matter in these soils was blown away, and was a total loss. (See Figure 12–4.)

The sorting action of the wind during this windstorm removed most of the smaller soil particles. Drift sand had only one-fifth as many soil particles of the blowing size as the original soil. Most of the small particles in the wind-eroded soil were removed.

Windstorms removed an average of 0.85 inch of topsoil from fields near Salina and McPherson, Kansas, during March, 1950. About three-fourths of this soil was piled into drifts in the vicinity of the eroding field, and the rest was carried away, mainly as dust particles.

Each time the wind shifts the soil, more of the fine, lightweight material is removed, and the soil becomes sandier. After a number of shiftings, soil becomes sandy and less productive, and, if shifted enough, the total fertility of the soil may be removed. The remaining soil is low in productivity and drifts easily each time high winds blow. It also has a low water-holding capacity and cannot support crops during dry periods.

REDUCTION OF CROP YIELDS BY WIND EROSION

The loss of the fertility-bearing part of soil during the dust storms of the 1930's made the soil poorer and seriously reduced the fertility of the soils in the great dryland winter-wheat belt of the Southern

High Plains. First dust storms in this area reduced crop yields 4.5 times as fast as later storms. Productivity of land in cultivation thirty years was reduced 7 bushels per acre annually. Erosion accounted for 4.2 bushels of this loss, and removal of plant food by crops accounted for the remainder.

Plant food removed by crops was in relation to yields. Erosion reduced yields rapidly the first three or four years after the land was put in cultivation. This was the time the rich organic matter, silt, and clay were removed the fastest.

Erosion reduced the yield 0.52 bushels per acre per year the first four years after the land began eroding, but this rate dropped to 0.11 bushel for the next twenty-one-year period. Serious erosion usually began two to four years after the land was first put in cultivation.

Wind erodes all parts of loess soils. On loess soils (those laid down by wind) virtually all parts of the soil can be removed by wind. This is expected, since loess soils are derived from material previously laid down by wind. The individual particles of loess soils are uniform. Wind erosion does not alter the texture of either the residual soil, the drift, or that blown away. The organic matter content is also blown away at a uniform rate.

Wind removes all parts of muck soils. Muck soils are composed of plant residues reduced to a powdery type of organic matter. Individual particles are small and light, so when exposed to strong winds, the entire soil body is blown away.

WATER EROSION IS A SELECTIVE PROCESS

Water erosion is also a selective process—organic matter and the finer soil particles are removed first. This selective feature of soil erosion rapidly destroys productivity of cultivated lands.

Eroding surface soil in New Jersey contained an average of 15.8 per cent of particles less than 50 microns (.019685 inch) in diameter. Material eroded from this soil contained an average of 58 per cent of particles this size. The eroded material contained 4.7 times as much organic matter as the field soil, and also five times as much nitrogen, 3.1 times as much phosphoric acid, and 1.4 times as much potassium. The phosphoric acid in the eroded material was of the same availability as that of the eroding soil. The potassium in the eroded material was 3.7 times more readily available than that left in the original soil.

During a two-year period, a total of 207,849.6 pounds per acre was lost by erosion from a plot in Missouri. The plot was spaded four inches deep and left fallow (without a crop). The eroded soil contained 190.8 pounds of nitrogen and 90.94 pounds of phosphoric acid per acre. The eroding material contained 337.89 pounds of calcium and 69.61 pounds of sulfur.

Splashing of raindrops sorts out lightweight particles. Raindrops beating on bare loams, sands, and sandy soils separate organic matter, silt, and clay from the sand. These materials are then floated away by surface flow, and the heavy sand is left on the field. This sand is turned under at the next plowing of the field or is mixed with the surface layer of the soil at the next cultivation. In either case, a fresh supply of topsoil is brought to the surface for further action by raindrop splash. Repeating this procedure over the years produces a sandier, less productive soil.

EFFICIENCY OF FERTILIZER LOWERED BY EROSION

Loss of organic matter and plant nutrients from the soil reduces the efficiency of fertilizer and the water-storage capacity of the soil Selective removal of plant nutrients by erosion had greater effect on crop growth in New York than the depth of topsoil. The use of liberal amounts of fertilizer failed to overcome effects of plant nutrient losses.

The more severe the erosion, the less the efficiency of fertilizer. Fertilizer was applied on all plots at the rate of 1,000 pounds per acre of 10 10-10

Yields of corn on Bath flaggy silt loam ranged from 27 to 88 bushels. The lowest yield was on the most seriously eroded soil. On a second soil type, the yield ranged from 40 to 106 bushels per acre. On still a third soil type, the corn yield ranged from 54 to 82 bushels per acre. In every instance, the yields were consistently related to the amount of erosion.

Erosion reduces the efficiency of fertilizer in a number of ways. In the first place, it removes the organic matter and plant-food-bearing portion of the topsoil, thus lowering the amount of nitrogen and other plant nutrients available for the growing crop. Erosion also seals the surface of the soil against the intake of rain water, which means there is less moisture in the soil to dissolve the plant food in the fertilizer and soil. There is less moisture to support vigorous plant growth. The loss of the organic matter also produces

a less favorable physical condition in the soil. During times of extremely heavy rains, much of the topsoil is removed, and part of the fertilizer goes with it. The loss of this soil reduces the depth of the remaining topsoil, restricting the area in which plant roots get water and plant food essential for vigorous plant growth.

For these reasons, crop increases obtained from the use of fertilizer on eroded soils are usually much lower than on less severely eroded soil of the same type.

Exercises

1. The next time there is a hard rain in your area, get about a gallon of muddy water out of a drainage ditch in the field. Pour it over a filter paper in a funnel to remove the mud. Dry the mud. Rub it between your thumb and forefinger. Notice how fine it is. What does it consist of?

2. Find a saucer-like depression in the field or on a slope that flattens out suddenly at the base of a hill. After the water has had time to dry up from the next hard rain make a careful study of what you find in the depression or at the base of the hill. Notice how different the material you find here is from the main soil.

3. Find a cut in a road bank or take a spade and dig a hole two or three feet deep. Notice that the soil is made up of definite layers The top layer has most of the organic matter. It usually is dark in color, or darker than the rest. This is the A horizon or topsoil. The next layer immediately below this is just as characteristic as the topsoil, except it has little or no organic matter and has a different color. The soil material is a lot different, too. This is the B horizon or subsoil. Can you explain why these two layers of soil material got that way?

Questions

1. Why is erosion so destructive to soil? How does it destroy our soil?
2. What is the main source of loss of plant food from soil? How is this brought about?
3. Why is fertility erosion so damaging? What has happened to most of our plant food by the time it is realized that the soil is eroding?
4. We have made tremendous improvements along some lines in crop production, but our yields have not kept up with these improvements. Why?
5. How do we know plant food and organic matter are removed from our soil by erosion?
6. Why has it been so difficult to build up the organic matter content of our soils? What proof can you give of this?

7. How does Nature build soil? What portion of the soil is most productive? Explain why this is. What is the main difference between rotten rock and soil?
8. Why is the loss of topsoil so serious? Is it possible to regain such losses?
9. How does wind make a soil sandy? Which dust storms are most destructive? Why?
10. What do we mean by saying erosion is a selective process?

13

Water Erosion Control on Cultivated Land

WE learned in Chapter 3 that water eroded soil by applying force at the surface of the ground. This force comes from two different sources: One is the falling raindrop, and the other is the water that flows over the surface of the ground. Falling raindrops apply their force when they strike bare ground, and it far exceeds that applied by flowing water.

Flowing water applies its force against the ground surface as it flows over the surface of the ground. There are two types of force involved: One is applied by shallow sheets of water flowing over broad surfaces, and the other is applied against channel bottoms and sides after water collects in channels.

The force applied by shallow sheets of water flowing over broad surfaces moves loose soil particles but does not tear the soil loose—that is, it only moves what is already torn loose. After water collects in channels, the force used against channel bottoms and sides does loosen that soil. This force is applied at the surface along a line parallel to the surface of the ground in channels.

Since falling raindrops apply their force from above, it would seem that measures aimed at controlling surface flow would be ineffective against the raindrops. On the contrary, measures aimed at controlling falling raindrops also control, to a large extent, forces applied by surface flow.

The way in which falling raindrops speed up erosion is to blast

soil particles loose from the surface. The way in which flowing surface water aids in erosion is by moving soil that is blasted loose by falling raindrops. When surface water collects in channels, it then aids erosion by tearing soil loose from the bottom and sides of channels. By keeping surface water churned up, falling raindrops also aid flowing surface water to move soil, enabling the flowing water to keep more soil in suspension, or suspended in water. This also keeps the soil from settling out, thus increasing the amount of soil that flowing surface water moves off the field.

Measures that control raindrop splash keep raindrops from striking bare ground. They remove the energy or force from the raindrop before it comes in contact with the ground. To do this, such measures must be in the form of a cover or roof, so that they will intercept or catch falling raindrops before they strike the ground.

Plant cover in the form of growing plants, plant trash, or plant residue make good roofs. They serve as shock absorbers by catching falling raindrops, breaking them up, and easing them to the ground

Figure 13-1. *The maximum amount of damage is done during periods of hard rains when the falling raindrop and surface flow team up on bare land. The silt forming the deposit in the foreground was blasted loose from the surface of this inadequately protected Kansas cornfield. The splashed material fell back into the shallow sheet of water on the surface of the ground and was floated downhill. Had the corn provided adequate cover to protect the soil against the impact of the falling raindrops, there would have been little erosion* (Soil Conservation Service Photo)

as clear water. They rob raindrops of their power—remove their sting, so to speak, and make them harmless.

Measures for controlling raindrop splash, then, are aimed at building a roof over the field. To be successful, they must provide, over the entire field a roof that is not spotty or full of holes, that is continuous, that is there all the time.

A good roof of plant cover completely controls raindrop splash and also aids in preventing damage from flowing surface water. It does this in at least four main ways. First, plant cover increases the amount of water absorbed by the soil and, at the same time, decreases the amount of water for runoff. Second, plant cover protects water on the ground from falling raindrops. Raindrops don't strike the water and keep it churned up. Third, plant cover slows the flow of water over the ground. Fourth, plant cover tends to keep flowing surface water spread out and does not let it collect to form channels. It also protects the bottom and sides of channels from flowing water.

The only way we can control raindrop splash, then, is to keep raindrops from striking bare ground by putting something between raindrops and the bare ground.

Methods aimed at controlling scour erosion, or erosion from flowing surface water, differ from the roof idea. Here, we must throw obstructions in the path of flowing water to keep it from collecting or concentrating to form channels and from spreading in shallow sheets. Next, we try to control the flow once it becomes channelized. We try to control it after it gains tumbling motion or power to tear the soil loose.

CONTROL OF RAINDROP SPLASH

We find there are three main steps in developing a program to control erosion by raindrop splash. We first learn about the rains that occur during the year. When do they come? How hard are they? What month or months do the hardest rains come? In fact, we need to know all we can about when rains splash our soil.

Second, we need to know what condition our soil is in at the times the hard rains come. How much plant growth does it have? What kind of crop is on it? What kind of roof does it have? How well does this roof work? What must we do to make the roof effective?

Third, we plan a cropping program, which must contain crops we need for food and feed, must contain crops we need to sell for money to buy clothes and other necessary things, and must provide a roof to protect our soil from raindrop splash. Remember, each of

these steps is important, so we can't neglect any one; least of all can we afford to neglect our roof. We usually can find information about rains in Weather Bureau records. We want to know how much rain we get, when it comes, how it falls (how hard or intense).

Most of our erosion is caused by a few hard rains. In some areas, a half dozen hard rains may cause 80 per cent or more of our erosion. In practically all areas, only a small portion of the rains cause over half of the erosion. We can determine the season or seasons in which these rains occur by studying Weather Bureau records.

Our records from the Arnot Soil Conservation Service Experiment Station at Ithaca, New York, illustrate this point. Twenty-one rains accounted for 65 per cent of the total soil loss during a period of eight years and seven months, which was less than 12 per cent of the 177 rains that fell during that period. Two of these rains caused 17.7 per cent of the soil loss.

A breakdown of the 177 rains into intensity groups illustrates the importance of the rainfall intensity on soil erosion. Records of these rains are listed in eight different groupings (a grouping is based on maximum rainfall for a fifteen-minute period). The amount of soil lost by erosion during each group of storms is presented in Table 9.

TABLE 9

NUMBER OF RAINS CAUSING 0.5 TON, OR OVER, OF SOIL LOSS PER ACRE, AVERAGE RAINFALL, MAXIMUM RAINFALL INTENSITY FOR FIFTEEN-MINUTE PERIOD AND SOIL LOSS PER ACRE AT ITHACA

Number of Rains	*Average Rainfall* (inches)	*Average Maximum Rainfall* (inches per hour)	*Soil Loss* (pounds per acre)
55	0.54	0.50	8
29	0.59	0.62	57
33	0.68	0.77	232
12	0.77	1.14	721
27	0.94	1.50	1,594
9	1.12	2.16	3,527
10	1.73	2.73	5,704
2	1.35	4.00	14,427

IMPORTANCE OF RAINFALL CHARACTER GREATER THAN THE AMOUNT

How hard rain falls is more important in the cause of erosion than the total amount of rain. Slow gentle rains are not nearly so destruc-

tive as hard rains. Rain falling in a short time is more damaging than equal, or even larger amounts, falling over a longer period. A larger portion of water falling during slow rains is absorbed by the soil, so it is during hard rains that raindrop splash and surface flow team up to cause the greatest damage.

Fifty-five of the rains had an average total rainfall of 0.54 inch. These had an average maximum intensity of 0.5 inch for a fifteen-minute period. The average soil loss by erosion for this group was 8 pounds per acre. The next least erosive group had an average total rainfall of 0.59 inch, with a maximum intensity of 0.62 inch for a fifteen-minute period. Soil loss was 57 pounds per acre. This group had twenty-nine rains.

Total rainfall in this group was only 0.05 inch over the first group. The maximum intensity increased 0.12 inch over the fifteen-minute period, but the soil loss increased from 8 to 57 pounds per acre.

Increasing the intensity from 1.5 to 2.16 inches per hour, for a fifteen-minute period, increased the soil loss more than 121 per cent. The higher intensity rain produced only 0.18 inch more of the water than the slower rain. Falling at a maximum rate of 4 inches per hour for a fifteen-minute period, 1.35 inches of rain water removed 14,427 pounds of soil per acre. A 1.73 inch rain falling at a maximum intensity of 2.73 inches per hour for a fifteen-minute period removed only 5,704 pounds of soil per acre. The second rain supplied 0.38 inch more water than the first, but it removed only about one-third as much soil because it didn't fall as hard.

Other rainfall data from the Arnot Station show that the greatest damage occurs during the period of June to September, inclusive. The average annual numbers of excessively heavy rains were eight during June, eleven during July, fourteen during August, four during September, and one during October. No excessively heavy rains occurred during any of the other seven months.

If data on excessive rains are not available, total rainfall by months may be used; although it is not as reliable as excessive rains, it may serve. The superiority of intense rains is illustrated by data in Table 10 from Guthrie, Oklahoma. The period of greatest total rainfall runs from April to November, inclusive, which coincides only roughly with the period of highest fifteen-minute maximum intensities. This period extends from April to October, inclusive. April, May, June, August, and September are the months having a large number of excessively heavy storms.

TABLE 10

AVERAGE ANNUAL RAINFALL, MAXIMUM FIFTEEN MINUTE INTENSITY AND EXCESSIVELY HEAVY STORMS BY MONTHS AT GUTHRIE, OKLAHOMA, DURING AN ELEVEN YEAR PERIOD

Month	*Rainfall*	*Maximum Fifteen Minute Intensities*	*Excessively Heavy Storms**
	(inches)	(inches)	(number)
January	1.45	0.31	
February	1.44	0.87	0.1
March	1.87	0.93	0.3
April	2.60	1.67	0.9
May	4.37	2.45	1.6
June	3.73	2.08	1.6
July	1.63	1.72	0.5
August	3.42	2.08	0.9
September	3.67	2.13	1.1
October	1.97	1.15	0.5
November	2.56	0.60	0.2
December	1.50	0.43	

* Average annual for seventeen year period

Erosion-producing storms do not necessarily occur the same months in different areas (See Table 11.) This table gives the number of excessive storms by months for varying periods of time at five different locations. The months of intense rains at these localities are in the period of May through September.

TABLE 11

AVERAGE NUMBER OF EXCESSIVE STORMS BY MONTHS FOR VARYING PERIODS AT FIVE DIFFERENT LOCATIONS

Month	*Bethany, Mo.**	*Clarinda, Ia.†*	*Hays, Kan.‡*	*La Crosse, Wis.§*	*Statesville, N. C.¶*
January					0.3
February					
March	0.1		0.1	0.1	0.8
April	0.1	0.8	0.1	0.5	0.3
May	1.4	1.1	0.8	0.7	0.7
June	1.8	2.1	1.4	1.5	1.7
July	1.0	2.0	0.6	1.5	2.0
August	1.5	1.0	1.1	1.2	3.0
September	0.9	0.8	1.0	1.1	0.3
October	0.4	0.5		0.3	0.8
November	0.1		0.1	0.1	0.5
December		0.1			

* Average annual for 10 years
† Average annual for 8 years
‡ Average annual for 9 years
§ Average annual for 15 years
¶ Average annual for 6 years

AMOUNTS OF COVER REQUIRED

Tests conducted in Texas and Oklahoma show that 657 pounds of range-forage cover per acre reduced the amount of raindrop splash by 73 per cent. The same tests showed that 1,292 pounds of range-forage cover reduced raindrop splash by 93 per cent; with 1,865 pounds of cover, it was reduced by 96 per cent, and with 5,592 pounds of cover, it was reduced by over 99 per cent.

The use of 750 pounds of buckwheat straw per acre as mulch at Ithaca, New York, reduced soil loss to less than one-fourth. Present indications are that from 4,000 to 6,000 pounds of plant cover (dry weight) per acre are needed. This includes both standing forage and crops and litter. We find soil splash increases rapidly as the amount of cover falls below 2,000 to 3,000 pounds per acre. For effective control, we need approximately 2,000 pounds per acre of short sod grasses, 3,500 pounds of ordinary crops or grasses, or 6,000 pounds of tall, coarse crops and weeds.

For soil protection, range plants and crops can be grouped according to growth form into three classes: (1) ordinary crops and grasses, (2) short sod grasses, and (3) tall, coarse crops and weeds.

The effectiveness of plant cover is determined by how well it keeps falling raindrops from striking bare ground; how well it covers the ground. Low-growing, dense, sod-forming plants cover the ground completely and catch practically all raindrops. They make effective cover. Such crops as small grains do not cover the ground as well, so they let some raindrops through and are less effective. Larger amounts are required to give equal protection. Tall, coarse crops like cotton and corn are less effective than small grain, because they have open foliage that leaves large areas of the ground unprotected. Still larger amounts of these crops are required for protection.

Differences in growth forms disappear when the amount of cover is expressed as "effective weight." Effective weight takes into account the degree of surface coverage and the total cover weight, which is especially useful in judging cover of unusual growth form or irregular distribution on the ground. When plant materials are of average form, either the weight or coverage alone is a satisfactory indicator of effectiveness in preventing splash. By average forms, we mean the grains, fine-stemmed legumes or mid-grasses, uniformly spread over the ground. Coarse, woody residues of the sor-

ghums or cotton, on the other hand, may weigh heavily when they cover a very small percentage of the soil so offer little protection from rains. Tall open-growing crops like the sorghums, or tall weeds on range land, produce large tonnages in proportion to their coverage. In such cases, we take into consideration both weight and coverage.

Effectiveness of cover in reducing splash is inherent in the cover itself and is independent of the soil on which it occurs. These values are applicable to any example of plant cover on any site and in any rain. Table 12 summarizes these results, which are given in terms of average amounts of cover required to provide different degrees of effectiveness in controlling soil splash.

TABLE 12

AMOUNTS OF COVER REQUIRED TO CONTROL SPLASH
AVERAGE AMOUNTS FOR DIFFERENT DEGREES OF EFFECTIVENESS

	Single Measurements				*Dual Measurements*	
Effectiveness (per cent)	*Total Weight* (pounds per acre)	*Soil Coverage* (per cent)	*Forage Density* (per cent)	*Average Height* (inches)	*Effective Weight* (pounds per acre)	*Volume* (cubic inches per square inch)
98	5,000	85	90	10.00	3,000	3.50
97	4,000	70	75	8.00	2,000	2.50
95	3,000	55	60	5.00	1,000	1.00
90	2,000	35	40	3.00	600	1.00
85	1,650	25	30	2.50	425	0.75
80	1,400	23	25	2.00	350	0.60
75	1,250	20	22	1.75	275	0.50
70	1,100	18	20	1.50	200	0.45
65	1,000	15	18	1.25	175	0.35
50	750	10	12	1.00	100	0.25
40	600	8	10	0.70	65	0.20
35	500	7	8	0.50	50	0.15
25	350	5	5	0.40	25	0.10

SOIL SPLASH UNDER FIELD CONDITIONS

The amount of soil that splashes under field conditions is the combined product. It depends on the character and condition of the soil, the amount of cover present, and the character of the rain.

Soil splash was measured under actual conditions, and measurements showed that cover controls splash erosion. On every soil tested, maximum cover on both range and crop practically eliminated splash regardless of the character of the soil. Thus, if there is enough cover to intercept all the drops before they reach the soil, even the most easily eroded soil is safe.

PLANT COVER REDUCES SOIL SPLASH

The amount of soil splash on croplands, in relation to the weight of cover on the ground, follows the same general trend as on grasslands. Cropland follows at a higher level because cultivated land is more easily eroded.

Regardless of the erodibility of the soil, the amount of splash on croplands declined. This decline was a straight line relationship—that is, the rate of decline went down as the amount of cover increased. It is the amount of cover, not the kind, that protects farmland from raindrop splash.

The method of harvesting a crop and management of the residues may make a greater difference in its protective value than the kind of crop. Any plant material on top of the ground is helpful For the same reason, roots of crops do not protect from splash erosion, because roots cannot protect the land from raindrops unless they are on top of the ground.

INSUFFICIENT COVER PROVIDED BY CULTIVATED CROPS

Figure 13-2 shows the extent of the rainfall hazard by months, indicates the resistance offered by the soil to the hazard and the amount of protection supplied by the cropping system, and illustrates the failure of cultivated crops to provide cover enough to absorb raindrop impact. The chart in the upper part of the figure shows the raindrop hazard by months that is measured by the number of excessively heavy rains, for the period of March to October, inclusive. No excessively heavy rains were recorded during the months omitted from the chart. The lower half of the figure shows the protection against the raindrop impact provided by the crops used in the rotation.

The major rainfall hazard occurs during the months of June to August, inclusive, but a fairly high degree of hazard also occurs in September. The peas supply adequate protection during May and the first half of June, and are harvested for canning about June 15. This removes the vines from the field at the beginning of the high-rainfall-hazard period, June to August Bare ground is exposed to the impact of raindrops until the cover crop of rye-vetch can become established and produce sufficient cover to absorb the impact. The land is without satisfactory protection during most of the pe-

riod from mid-June to mid-August. This cropping system does not protect the soil against raindrops.

The pea vines should be left on the field as mulch. The rye and vetch should be planted through the mulch, which probably would provide the needed cover.

The same test can be used to determine whether or not a given crop rotation provides adequate cover. In this case, we use two charts that cover the period of the rotation. The rainfall hazard

Figure 13-2. Outline illustrating a gap in the protection provided by a crop in a rotation and the following winter cover crop. On this farm the application of organic matter, fertilizers, crop rotation, cover cropping, and contouring are not sufficient.

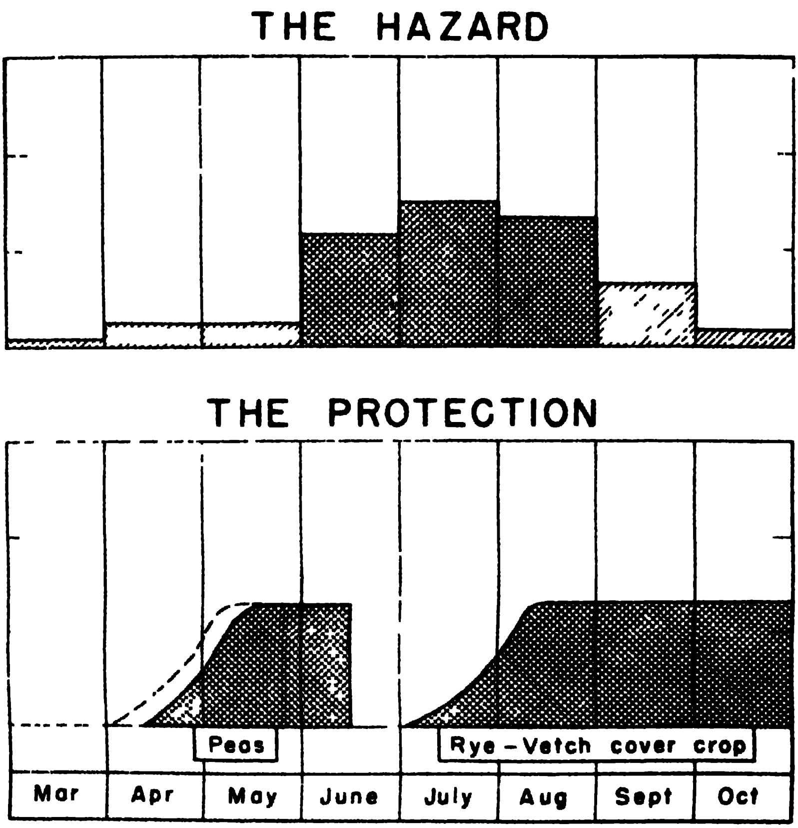


chart is the same for each year of the rotation The protection chart shows the protection provided by the crops used for each season of each year of the rotation (See Figure 13-3) The same rainfall hazard is used for two crop rotations

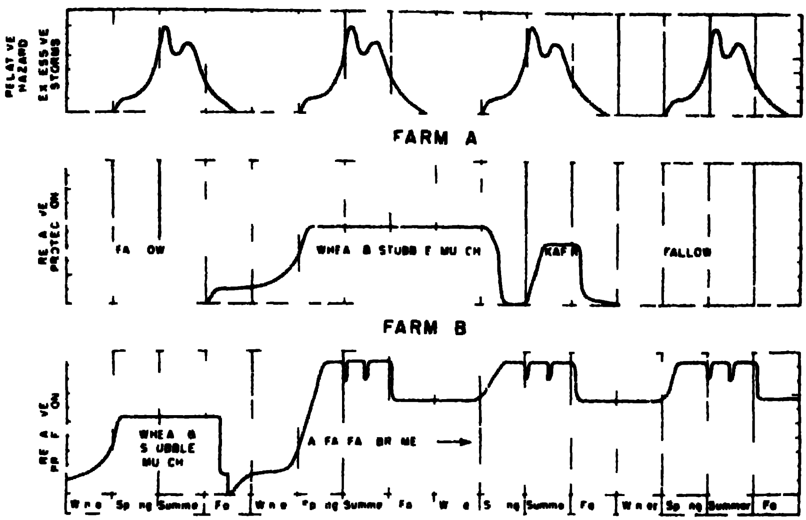


Figure 13 3 Outline illustrating the occurrence of the hazard (excessive storms) and of the protection (obtained from agronomic practices) on two different farms in the same area during a four year period

The rainfall hazard begins in early spring and increases until it reaches a peak in June It remains high throughout the summer and declines gradually during the early fall It disappears the latter part of the season

Farm A is cropped to a four year rotation of fallow wheat kafir-fallow The fallow years give no protection against raindrop splash, except the little provided by kafir stubble during the second year The wheat year, when stubble mulch tillage is practiced, provides fair protection throughout the year, but kafir does not furnish protection until after the peak of the rainfall hazard has passed The maximum protection supplied by the kafir during the latter part of the summer is inadequate

The four-year rotation practiced on Farm B supplies even more protection. This rotation program consists of one year of wheat and three years of alfalfa-bromegrass-hay. Stubble-mulch tillage is practiced during the wheat year, and, as a result, fairly adequate cover is provided during the entire rainfall hazard period. The alfalfa-bromegrass-hay supplies enough protection during the last three years of the rotation

The cropping system shown in Figure 13-2 does not supply the plant cover needed Neither does the four-year rotation on Farm A in Figure 13-3

Under field conditions, where row crops are grown, it may be difficult or impractical at times to develop cropping systems to provide enough cover at the proper time In these cases, additional cover must be supplied, which can be done by leaving residues from crops on top of the ground

We also find plant cover reduces frost penetration depth—that is, the depth ground freezes Protective value is determined by its height and density The chief effect of plant cover on frost penetration is its ability to trap and hold snow The insulating effect of the plant cover on the ground is important, but its ability to catch and hold snow is more so Usually, the depth of snow is more uniform in vegetated than in plowed fields, so that ground covered with a fair amount of plant cover does not freeze as quickly as plowed ground

Crops should be harvested in such a way as to leave high stubble Then, sufficient snow may be trapped and held throughout the winter to keep frost penetration to a minimum This protects the soil and reduces runoff and erosion losses later in the season

PREVENTION OF SPLASH EROSION BASIC TO SOIL IMPROVEMENT

Raindrop splash accounts for the main losses of organic matter by erosion Larger amounts of plant nutrients are removed by this process than by crops Further many of the plant nutrients added to the soil in the form of commercial fertilizers are removed by splash erosion, which also destroys the physical properties of the soil This increases runoff and decreases the amount of water available for plant growth

Splash erosion holds the key to soil improvement programs. By providing effective plant cover year round, we are laying the basis for permanent soil improvement

CONTROL OF SURFACE FLOW

The rainfall that does not find its way into the soil by percolation, or is held in depressions on the surface of the ground, becomes runoff water. When runoff water from one small area is allowed to run down the slope, it joins with the runoff water from other areas. Because it soon increases in volume as well as velocity, runoff water gains tremendous power as it moves downhill.

We need to prevent water from concentrating to form channels, and we also need to regulate its flow. Both these objectives are accomplished by controlling the length of slopes over which the water moves. Where slopes are steep or long enough to favor damaging concentrations and velocities they need to be shortened. We do this by establishing suitable barriers at strategic distances. The most popular barriers now in use for shortening slopes include the terrace, contour cultivation, and contour strip cropping.

By terracing the field, the slope is divided into small watersheds. The short slopes thus formed, plus the use of a cropping plan, soil treatment, and cultural practices fitted to the field, allow a minimum of water to attain scouring velocity. By controlling the velocity of flow, soil loss by scouring is reduced, and more runoff water may be absorbed as it moves slowly from the field.

Terracing. A terrace is an embankment or ridge of earth with a channel on the upside constructed across a slope. The purpose is to control runoff and reduce scour erosion. Terraces may logically be divided into two types on the basis of their primary functions: level and gradient Both types are alike in that they are used to control water and reduce scour erosion; they differ in that the level terrace is used to conserve moisture. The gradient terrace is used for the orderly disposal of surplus water during times of excess rainfall.

A level terrace is used in areas of low rainfall. The extra water conserved is needed for crop growth. The gradient terrace is recommended for humid conditions where conservation of moisture is not a major function as a rule. Terraces do not protect the soil from splash erosion, however.

Contour strip cropping. Strip cropping is the practice of growing crops in a systematical arrangement of strips or bands, which serve as vegetative barriers to wind and water erosion. In contour strip cropping, the strips are laid out on the contour.

One means of utilizing the high erosion-control value of close-growing crops is to adopt a contour strip cropping pattern. Instead

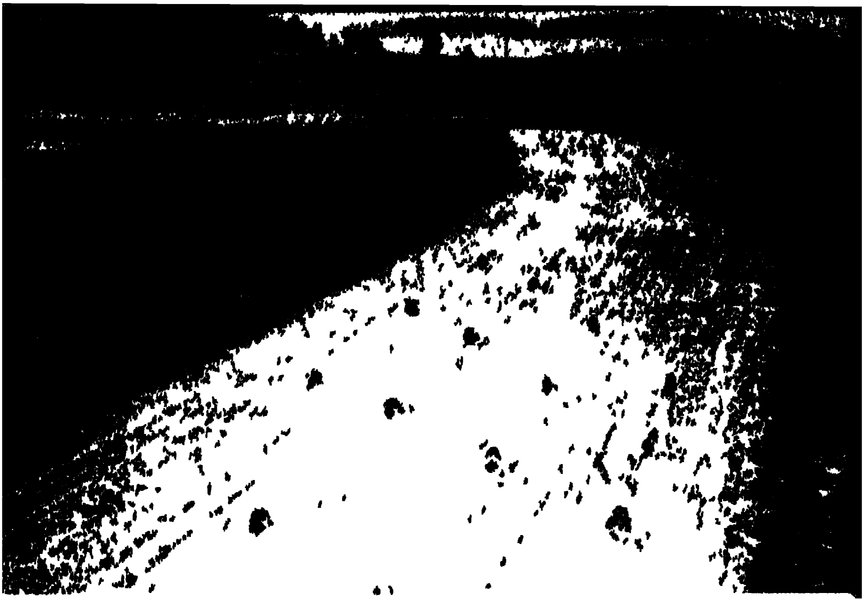


Figure 13 4 A contour stripped field in Iowa Strips of small grain are alternated with strips of corn (Soil Conservation Service Photo)

of planting a field solidly to cultivated row crops plant alternate strips of row and close growing or sod crops. Once established, the sod crops usually provide ample protection from erosion, both by raindrop splash and surface flow to land actually planted to them. They provide no protection from raindrop splash for the strips planted to clean tilled crops, however. During rains of light to moderate intensities, the soil on the sod strip may be able to absorb the water that flows onto them from the clean tilled strips immediately above.

But during extremely heavy rains or rains of long duration, large quantities of water may flow from the sod strips to the clean tilled strips.

During rains of the last two types strip cropping may actually increase the rate of erosion by surface flow on the strips planted to clean-tilled crops. Under these conditions, flowing surface water moves from the clean-tilled strips onto the sod, immediately loses it turbidity, and then deposits its load. When it leaves the strip on the lower side (usually channelized) to enter the cultivated strip, it will be practically clear and will have higher eroding capacity.

Strips of various width of the soil-protecting crops are effective in reducing erosion and decreasing the distance of soil movement on

between-terrace slopes. Under some conditions, little or no soil moves from cultivated strips; under other conditions, large amounts are deposited on meadow strips. The amount of soil dumped in pastures indicates there is continuous erosion from the cultivated strip. In consequence, the quantity of vegetation in the meadow strip decreases and its quality deteriorates.

No one combination of crops or width of strips of the crops employed will be universally satisfactory. One requirement for success of the strip crop pattern is that the strips be laid out and maintained on the contour. If they diverge from the contour more than 4 or 5 per cent, for distances as little as 100 feet, much of the erosion-control effectiveness of strip cropping may be lost even on the least erosive soil types.

The effectiveness of strip cropping is influenced by soil type, degree and length of slope, previous erosion, and other factors. A wide variation exists in the effectiveness of a given strip crop pattern. This is especially true when used on soils of varying absorption capacities.

Figure 13-5. Sod strips in a contour strip-crop pattern do not protect the clean cultivated strip from splash erosion, as shown by this Texas field. During periods of heavy rain they may actually increase it. Clear water flowing from the sod strip onto the clean cultivated strip may have greater capacity to erode the soil than would have been the case if the strip had not been there. (Soil Conservation Service Photo)

Diverging as much as 2 per cent from the contour results in heavy losses with some soil types. Under no condition should it exceed 5 per cent

There is a relation between the degree and length of slope and the effectiveness of strip cropping, which is especially true when the strips are laid out within varying divergences from the contour. Losses are two to three times greater from soils with moderately heavy to heavy subsoil than from soils with light-textured subsoil

Previous erosion affects the amount of soil loss from the cultivated strip The more serious the previous erosion, the greater will be the loss with strip cropping

Even though erosion may be controlled on the areas planted to the sod crops, it does not mean erosion is not taking place on fields planted in strips Soil continues to erode on that portion of the field planted to row crops, even though it may be practically eliminated on the sod areas The eroded soil on the clean tilled areas moves on downhill and is deposited on the sod strips As these strips are alternated with row crops, the soil eventually reaches the bottom of the hill It then escapes from the farm into drainage channels The soil is on the move on the clean tilled areas, and eventually will reach the bottom of the hill With strip cropping, it takes longer for it to get away

Even though the soil may not actually be carried off the field, it is changing locations on the field This may result in damage that would be as serious as though it were carried away Strips planted to clean cultivated row crops should be provided with adequate plant cover to protect them from raindrop impact

Contour cultivation Contour cultivation, like terracing, is effective only in controlling erosion by surface flow More accurately, it is a part of the water disposal system When properly carried out, it is one of the most effective mechanical control measures for cultivated cropland Generally, it is effective from the standpoint of increasing crop yields, reducing runoff, and reducing scour erosion losses Like other measures, it has its limitations Maximum results may be expected only when it is used with other good farming practices Surplus water from contour cultivated fields should be emptied into grassed waterways to prevent gullying

During periods of heavy rains the water that collects in the middle of contour furrowed fields may spill over the ridges If this occurs at

Figure 13-6. Contour cultivation may hold water on a field longer during heavy or prolonged rains, as shown by this Oklahoma field. The middles may fill and overtop the ridges. When this overtopping occurs well up the slope, serious gully erosion may result. Contour cultivation does not protect the soil from raindrop splash. (Soil Conservation Service Photo)

a point well up the slope, serious erosion may occur on the down slope side.

Such factors as soil type, soil conditions, and amount of slope modify the effectiveness of contour cultivation. In the semiarid areas, the conservation of moisture is of primary importance. Contour cultivation by listing may be sufficient within itself in these areas. In more humid sections, contour cultivation may be adequate during periods of heavy rainfall for the orderly disposal of surplus water. During the drier growing seasons it may be used for moisture conservation. It is in those areas where contour cultivation serves this double function that appropriate supplementary measures are essential for maximum results. Contour cultivations should be used as a supporting measure, not as a substitute for plant cover.

Exercises

1. Select a bare spot of ground convenient to a water faucet or place soil in three shallow boxes or pans. Number these from 1 to 3. Play water on 1 from a garden hose for about five minutes as a light spray, on 2 as rain of medium intensity, and on 3 as hard rain. There will be little more than puddle erosion on 1, slight erosion on 2, and severe erosion on 3. Why these differences in the degree of erosion?

2. Fill two shallow boxes or pans with samples of soil of the same type. Use virgin soil or soil from a sodded area in one pan and soil from a cultivated field in the other. Expose to natural rainfall or play water on them from a garden hose as outlined in No. 1 above. Which sample erodes the more? What does this tell us about the effect of cultivation on the erodibility of soil?

3. Examine a terraced field immediately after a hard rain and before it has been cultivated. Note the small rills and in some cases gullies between the terraces. Also note the soil deposits along the terrace channels. Explain just what has happened here.

4. Follow the same procedure outlined in No. 3 above for a field that is strip cropped. Notice the signs of erosion on the strips planted to clean cultivated crops. Now examine the upper edge of the sod strips. Note the debris deposited by the water flowing from the clean tilled strip as it entered the sod strip. Examine the remainder of the sod strip for signs of erosion. What is the relation between the sod strip and the erosion on the cultivated strip?

QUESTIONS

1. What two ways does water erode soil? Which is the more important?
2. How do raindrops apply their energy or force to the soil? How does that differ from flowing water?
3. Do terraces, contour cultivation, and strip cropping stop erosion from raindrops? Why?
4. How can raindrop splash be controlled? How does this plan actually operate?
5. Why is it soils with good plant cover do not erode? Why is there so much erosion on cultivated land?
6. What kinds of rain do the most damage? What can we do to prevent rain from eroding our soil?
7. Where can we get information on rains and rainfall in specific areas? Which is more important—total rainfall or intensity of rainfall? Why?
8. How do crops differ in their ability to control splash erosion? What three general classes can crops be divided into from this standpoint? How much plant cover is needed with each class to control splash erosion?
9. How does plant cover affect infiltration? The loss of organic matter? The loss of plant food?
10. What is the main difference between cotton and corn and grasses and clovers from a soil improving standpoint? How does this compare with our present belief?
11. Can we improve our soil without the use of crop rotations? How would you do it?

14

Wind Erosion Control

TODAY, wind erosion is the most active destroyer of soil fertility in a number of areas, particularly the Great Plains. It is also active in local areas in a number of other parts of the country and very destructive in the spring and winter wheat areas.

Great Plains soils are noted for their high fertility. But this fertility, as in all soils, is bound up in the topsoil, the organic matter-bearing zone. It took Nature hundreds of years to build this rich topsoil. To lose it during a storm or a series of storms is to lose from crop production the fruits of Nature's efforts.

Soil blowing has increased in the Plains as new areas were brought into cultivation, because the natural vegetation was removed. Its beneficial effects on the soil were destroyed.

The greatest danger from soil blowing is in early spring, which is the season of high velocity winds in this area. Also in the spring the land is in most favorable condition to blow. Soil blowing may be serious any time of the year. During other seasons, it is usually better protected from wind. The soil should be protected at all times.

Any field without plant cover may blow if the soil is finely pulverized or tightly and smoothly crusted. The more sand the soil contains the greater is the likelihood of blowing. Once a field has started to blow, the condition grows worse unless control methods are used. During hard, sweeping windstorms, "eternal vigilance" and prompt action are necessary to detect blow spots. If they are neglected, blow spots may spread over vast areas.

The lands of the Plains region originally were covered with grass protected for countless ages. The plant cover was the best Nature

could develop under the circumstances. Under natural conditions, soil was less exposed to wind action even during prolonged droughts, because the residues of the last season's growth remained as a protective covering. This protected the ground until rains, however long delayed, came to stimulate new growth.

Wind erosion is a serious problem on many of our muck lands along the Atlantic and Pacific Coasts, as well as along the Great Lakes and other places. It also is a problem on mineral soils in local areas.

Destruction of natural cover when the land was put in cultivation or by overgrazing exposed it to wind. To protect the land, we must provide a substitute for this cover. Exposure of soil to wind for even short periods may result in severe erosion. Maintenance of an adequate plant cover, therefore, becomes the primary goal of all wind-erosion control efforts. Soil-blowing possibilities are greatest in seasons of drought, after crop failures, and on soil types of low water

Figure 14-1. Ridges check soil blowing temporarily by trapping drifting soil. If the wind blows long enough, ridged fields become level and the ridges lose their effectiveness. The middles fill with drifting sand and the crests are worn down by the wind, as is shown in this Oklahoma cotton field. (Soil Conservation Service Photo)

holding capacity. Wind erosion problems are greatest in areas where erosion-producing rains are least frequent. This problem decreases as rainfall increases.

In Chapter 4 we learned that wind erosion was begun by eddies twisting sand grains loose from the surface of the ground, thus starting saltation or a bouncing movement of these grains. These bouncing grains kick organic matter and smaller soil particles off the ground to cause dust clouds and loss of our plant food. Bouncing grains push and shove larger grains along the ground to form surface creep. We learned, too, that wind blowing slower than eight to nine miles per hour at six inches above ground can't move soil. This information gives us the clue to wind-erosion control.

Our job in wind-erosion control, then, is to keep the wind velocity at six inches above ground, below eight miles per hour. How do we do this? By putting so many obstacles in its path that it can't blow faster than eight miles per hour.

These obstacles have to be placed close enough together so that wind can't blow faster than eight miles at any place. They have to be high enough to affect the velocity of the wind six inches (or higher) above the ground, and they should be densest at the ground surface. Nature uses plants; so must we.

SOIL BLOWING

The rate of soil blowing decreases as the surface of the ground becomes rougher. The roughness of the surface is determined by the height of, and distance between surface obstructions.

The starting rate of soil movement over cultivated fields is less when the soils are ridged than when the soil surface is smooth, because ridges reduce the wind velocity. Slowing the velocity causes wind to dump some of its load in the middles. Ridges, however, produce greater velocities of wind flow over the crest of the ridge and also increase eddying. This results in a more rapid rate of erosion at the crest of the ridge. The initial net effect of ridging is a reduction in the rate of erosion. The field surface is gradually leveled. The middles are filled and the crests are worn down at the same time. When the field becomes level, the ridges lose their effectiveness, and erosion is resumed as if the ridges were never there.

Almost any soil will blow if the physical conditions are right. Sandy soils are perhaps the most susceptible. Soil conditions most

Figure 14-2. Destruction of plant cover by overgrazing exposed this soil to the damaging action of wind. This is typical of 175,000 acres of overgrazed pasture land in Crane and Ector Counties, Texas. (Soil Conservation Service Photo)

favorable for blowing are a smooth, finely pulverized surface free from a growing crop, weeds, or crop residues. A soil is least subject to blowing when it is covered with growing crops, weeds, or crop residue, or, if without cover, when it is rough and cloddy.

In the Great Plains, sandy and very sandy soils offer so little resistance to blowing they cannot be safely cultivated. They should be kept in or put back to grass. Heavy soils that form tenacious lumps and clods are least subject to blowing. Ordinary tillage practices can usually be employed with safety in these soils. Between these extremes is a large acreage of soils that are highly productive. Special precautions and treatments are necessary to prevent soil blowing on this group of soils.

Experience over the last twenty to thirty years in the 14- to 20-inch rainfall belt has revealed the dangers of farming these soils and has shown that none of the shallow, moderately sandy and deep loose sandhill soils can be kept productive under cultivation. Shallow hard lands (clay soils) have undergone severe erosion in all areas of less than 18 inches average rainfall. Nearly level, medium-textured, and moderately sandy lands, on the other hand, have withstood ero-

sion under rainfall as low as 16 inches. This was possible when suitable wind-erosion control practices were used.

Medium-depth hard lands have a fair to good record of performance. Where rainfall is less than 17 inches, alternate cultivation and grass is needed on these lands to prevent severe damage. Experience indicates that the hard lands erode more slowly than the sandy lands. If it is difficult to maintain crop residues and to get crop stands, it is a sign of overuse.

The length of time these soils can be cultivated safely varies with soils and climatic conditions. Deep, loamy sands in areas of 18 to 20 inches of rainfall are fairly safe. Cover crops should be used in the rotation. The deep, nearly level hard lands–the best of the High Plains wheat soils–can be safely farmed with appropriate precautions.

These findings parallel very closely the findings made in the prairie provinces of Canada. Here they found that regardless of conditions in different localities there are some definite principles that have general application. For example, summer fallow[1] may be used on medium loam soils under proper conditions. Sandy and clay soils require the protection of plant cover, which means that plowed fallow, though suitable on loams, is not safe on sand or clay unless protective cover crops are planted. These more difficult soil types, therefore, should be protected either with a crop or trash cover or both.

Wind with a wide unbroken sweep carries more drifting material than it does over narrow strips. Its sandblast action is greater on unstripped land, which is one reason why strip crop farming aids in wind erosion control.

One of the first requirements in controlling wind erosion is to determine the soil type and past cropping history. Areas not suited for cultivation should be planted to grass.

Although any fallowed piece of land may drift, some fallows have remained remarkably stable. Soils do not all erode with equal ease. For example, medium-textured soils do not erode as readily as others. Medium-textured loams that are not extremely high in organic matter do not drift readily unless improperly managed. Sandy soils and some clays are difficult to manage.

Soil with native plant cover or soil being cultivated for the first

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[1] Fallow is the tillage of land, without sowing it, for a season.

Figure 14-3. Rye was blown out of this South Dakota field two seasons in succession because there was not enough moisture to establish it. The third season the field was planted in strips with the results shown. (Soil Conservation Service Photo)

time is fairly resistant to wind erosion. Light sandy soils are extremely subject to blowing. It is practically impossible to summer fallow this type of land without serious danger of drifting. Fallowing this type of soil for moisture conservation also is of questionable value, and if done, it should be executed in those seasons when the soil moisture is not enough to justify seeding a crop. These soils should be seeded to grass and kept in pasture.

Where planted to grain continuously, a rotation of wheat and fall rye is commonly used in the spring wheat area. The rye is drilled into the wheat stubble. The rye stubble should be left until the following spring. The wheat may then either be seeded with a one-way disk with seeder attachment, or the land may be plowed, packed, and seeded immediately. Both crops are cut as high as possible, and the stubble is left standing to collect snow and protect the soil against wind erosion.

Soil drifting may occur on sandy soils despite these measures. It is necessary, therefore, to watch conditions in the fields at all times. When necessary, one should plow furrows through danger spots at the first signs of drifting. Knolls that are highly subject to drifting should be seeded to grass.

Clay soils are subject to drifting and are usually uniform in texture. Drifting may start in any part of a field or even an entire field

at one time. Once started, drifting is severe even in narrow strips. There is a rapid increase in drifting near the windward edge of a field of highly calcareous (limestone) heavy clay soil. This is followed by constant rate of flow along the remaining part of the field. Erosion increases progressively across the whole length of the field on loam or clay loam soil. Drifting piles equal amounts of sand in the stubble at the edges of each strip, regardless of the width of the strip. Stripcropping on this type of soil, therefore, has definite limitations.

Figure 14-4 Even sandy soils when protected by plant cover, are not subject to blowing. The sparse cover on this South Dakota field protects the soil against the action of wind. (Soil Conservation Service Photo)

Crops on clay soil are usually fair to good, especially where the crop is seeded on well-prepared fallow or on stubble land with good moisture reserve. To prevent soil blowing, this stubble must be kept anchored at the surface.

Loam soils show a wide variation in their susceptibility to blow, as a class they blow least. However, actual damage is by far the most serious when wind erosion occurs on these soils.

Once blowing starts, there is a gradual separation of the fine soil particles and organic matter from coarse sandy material. As blowing

Figure 14-5. This Montana farm is protected from wind action by the wheat stubble shown (Soil Conservation Service Photo)

continues, the soil becomes sandier. The greater the distance the material is moved, the more complete is the separation. It is important to check blowing where it starts, which is usually at a few vulnerable spots. It then spreads over the entire field. For this reason, stripcropping has proved to be a valuable aid in controlling soil blowing. This is especially true with loam soils.

Loam soils have a fairly good moisture-holding capacity. Under normal conditions, stubble from crops on fallow forms a good trash cover. In addition, these soils tend to retain a cloddy structure that helps to prevent wind erosion. Soil blowing on loam soils is relatively easy to control. The damage caused by blowing, however, is so severe that extreme precautions to prevent it are justified.

Maintaining a trash cover or a cloddy condition at the surface controls blowing in fields on strips up to 660 feet wide. If the stubble is light, it is advisable to seed a narrow strip of grain, about 50 to 66 feet wide, down the center of the wider strip before summer fallowing. This reduces the width of the crop strip to 330 feet or less. As conditions improve, these narrow strips can be eliminated.

WIND EROSION REDUCES CROP YIELDS

Topsoil to an average depth of about 9 inches has been removed from fields in western Kansas. This occurred during the nineteen years the fields were cropped to wheat. The soil was blown away,

and the loss included all the fertile topsoil This land is now much less productive and contains less organic matter and undecomposed crop residue than when it was newly broken

CROPPING PRACTICES AND WIND EROSION CONTROL

The best means of preventing wind erosion on cropland is to keep plant cover on the land continuously Effectiveness of plant cover in preventing wind erosion was shown during a duststorm at Salina and McPherson, Kansas, in March 1950 Soil blowing occurred only on fields that did not have enough plant cover Wherever the crop residue on the surface was a ton or more per acre, little or no erosion occurred But where the plant cover was not enough, topsoil to an average depth of about 0 85 inch was blown away

Plant cover reduces wind velocity and also catches, or traps, sand grains moving in saltation The wind can neither pick up soil grains nor keep them moving once they start

The amount of wheat stubble or straw required to prevent wind erosion varies with the erosiveness of the soil and the velocity of the wind The higher the velocity of the wind the greater the amount of crop residue required

Figure 14 6 Soil drifting usually starts in a few vulnerable spots, like the one shown in this Texas cotton field (Soil Conservation Service Photo)

Studies in Canada showed an increase of five miles per hour in wind velocity, one foot above the ground, doubled the amount of cover needed Short stubble gives less protection than an equal amount of longer stubble Stubble gives less ground coverage than an equal weight of straw, but stubble is less apt to be removed by high winds A combination of straw and stubble gives more protection than equivalent amounts of straw or stubble alone

Figure 14 7 One-way disk being used on wheat stubble in Oregon The machine should be set to run shallow and leave all the straw possible on the surface (Soil Conservation Service Photo)

Cropping systems and cultural operations should be aimed at maintaining covers of growing crops or undecomposed residues The condition of the plant cover is determined largely by the method of tillage

Crops often leave the surface in condition to blow When such crops as corn and sorghum are harvested, the stubble should be left a foot high or higher Additional protection is obtained by leaving two rows in twenty standing If these crops are pastured, the stock should be removed while there are still enough stalks with leaves at-

tached to furnish protection. Stripcropping aids in the control of soil blowing by shortening the distance that loose soil can move. If the strips are laid out on the contour, water also is conserved. Added water helps prevent blowing.

The land should be tilled in such a way as to cause the least soil disturbance. For example, weeds should be controlled by subsurface tillage or chemicals, the ground should be cultivated only when moist; the soil should not be pulverized by tillage tools, and corn and sorghum stubble should be cut to leave a large amount of leaves. Land left over winter in grain stubble or with a cover of weeds will not blow. Usually winter wheat with a good fall growth protects the soil.

The wind erosion problem is so complex that a combination of measures is needed. Preparations ten to twenty months in advance of probable blowing can be made in connection with productive crop management. This preparation will protect the capital investment and prevent expensive repair operations.

Among the crops adapted to southern Great Plains conditions that produce suitable residues are the winter and spring grains—wheat, barley, and rye. Of these, winter wheat is of foremost importance. Grasses grown for seed, hay, or pasture are excellent erosion-control plants. All members of the sorghum family produce good stubble,

***Figure 11-8.** This Texas field was seeded to grain sorghum in June, 1948, for stubble in which to seed sideoats grama the following spring.* (Soil Conservation Service Photo)

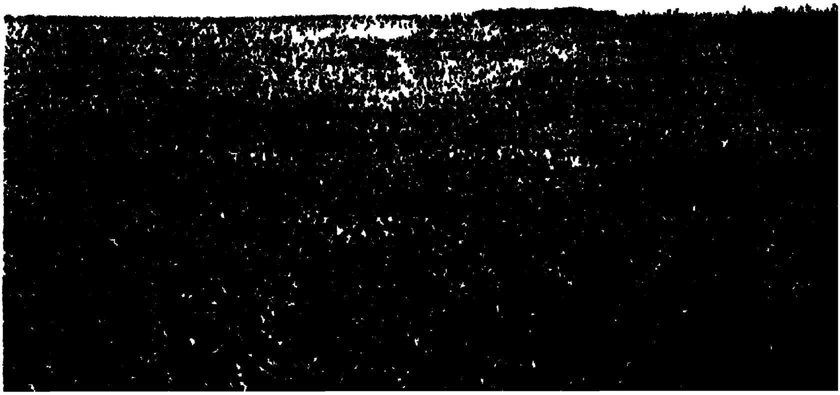


Figure 14-9. The amount of corn residue in this photograph is not enough to prevent soil blowing. (Soil Conservation Service Photo)

but the mere growing of a crop does not necessarily insure protection. Enough residue must be left to keep the wind velocity low enough so it can't start soil moving. The residue should be left standing and planted through, thus assuring a renewal of the residue supply.

The practice of burning stubble and overgrazing stalk fields has no place in a wind-erosion control program. Some of the most severe wind erosion in the southern Great Plains is due to these two practices. Rank wheat stubble has often been burned because of the mechanical difficulty of working it into the soil. Temporary fertility depression often follows when the stubble is retained. These are more than offset by the protection given the soil when the stubble is left unburned and by the ultimate increase in productiveness.

Methods have been developed for leaving this straw on the surface of the ground and planting through it. The temporary depression in

crop yields can be overcome by proper use of nitrogen. Another practice is that of renting stalk fields to outside herdsmen. They almost always leave the cattle in the field until the last scrap of vegetation is consumed. Moderate stalk-field grazing benefits farm livestock, but the livestock should be removed before the ground cover is destroyed.

Where sorghum is cut with a binder for fodder, enough cover should be left, and this can be done by leaving one-foot-high stubble, or by leaving regular strips four to six rows wide of headed stalks. These strips should be left every twenty to thirty rows. A good stand of any of the sorghums will protect the soil from wind if this rule is followed.

Figure 14-10. Although this Texas field is subject to severe erosion, it has never suffered severely, because sorghum stubble is always left standing as long as is possible without interfering with planting the next crop. (Soil Conservation Service Photo)

When corn and clean-tilled crops other than sorghums are grown, stripcropping with sorghum or suitable grass is necessary. On light sandy soil, the rows should run at right angles to the direction of the prevailing winds. The sorghum or grass strips should be spaced close

enough to protect the other crop. Windbreak strips should be not less than four rows wide. Under severe blowing conditions, the width of main crop strips generally should not be greater than twenty rows. The actual width will depend on soil type, direction of rows, and type of crops involved. Under severe erosion conditions, strips as narrow as five rows may be practical.

No rigid system of either continuous culture or rotation has been devised that equals a flexible cropping plan. Such a plan takes into consideration the soil-moisture and fertility conditions of individual fields at each successive planting period. Crops should be selected that provide maximum cover under varying conditions.

Dependability of crop production under the variable system assures a continuous plant cover. Need for emergency crops depends on the success in producing and maintaining residues.

Properly managed, normal residues of cultivated crops in the winter wheat areas provide ample cover, except during periods of prolonged drought. Where no plant cover is produced, steps should be taken to assure maximum absorption of water by the soil for use by the next crop. Emergency cover crops may be planted when there is not enough plant cover. Perhaps the summer has been too dry to produce a crop, the surface residue has disappeared or the rains occur in late summer. If so, a stooling sorghum such as Sudangrass or dwarf milo should be planted under such conditions. These renew the ground covering for the winter. When winter wheat might fail leaving the land bare, a dual-purpose planting of wide-row sorghum for grain should be made as a substitute for summer fallow. Milo or similar crops grown in rows ten to fifteen feet apart give a partial fallow effect; at the same time, they protect against blowing until wheat is again planted the following fall. Beans, cowpeas, and similar crops should be grown in strips between the strips of sorghum, Sudangrass, or corn.

Adequate supplies of soil moisture hold the key to successful maintenance of ample crops and crop-residue cover. Those practices that are most effective in controlling wind erosion are also effective in getting greater amounts of rainfall into the soil. The use of plant cover, contour cultivation, and level closed-end terraces is important in this connection. These practices are effective in reducing runoff even during the hardest rains.

In the spring wheat areas, the practice of fallowing leaves large areas of bare land. The practice of plowless fallow, leaving all resi-

dues on the surface, is the most effective method for preventing soil blowing. However, under certain conditions it breaks down, also. Under this system, twenty-one months or more must elapse between the harvesting of one crop and the growth of the next. Near the end of this period, when protection is most needed, residues may be so decomposed as to be of little value for protection against wind.

In some spring wheat areas, stripcropping is used to prevent soil blowing. The crops are managed in order to produce the best cover possible. Cover crops are seeded on fallow, usually about August 1, as an additional protection. If the cover crop does not exceed six inches in height, little reserve moisture is lost from the fallow. The moisture used up by the cover crop may be regained by additional amounts of snow trapped. Thus, yields on cover cropped fallow are often about equal to those on bare fallow. Pasturing cover crops but not destroying their protective value is feasible and profitable in some regions.

Considerable acreages of cultivated land in the southern Great Plains are too sandy or have too little rainfall for dependable annual crop production. These lands should be put back to grass. Other parts of the western sandy lands are capable of producing excellent crops, especially sorghums. If they are farmed in large blocks, soil

Figure 14.11 Windbreaks on a sandy land farm in Foard County, Texas. The barren area to the left is due mainly to sterile sand trapped by the trees. (Soil Conservation Service Photo)

drifting may, at critical times, spread quickly from one field to another. Eventually this involves whole neighborhoods.

Farmed fields should be small and guarded by permanent plantings of grass or browse plants. With reasonably sized holdings, soil blowing should be controlled, because proper management of crop cover and proper methods of cultivation make it possible. This is true even in years of drought. Regrassing on the shallower sloping and sandier portions of the Plains is important.

Legumes and grasses used in rotation with field crops are effective in reducing blowing on irrigated areas. For example, in Nebraska land in potatoes after forty years of cropping was most subject to erosion. With a three-year rotation of potatoes, beets, and barley the land lost 74,000 pounds of soil an acre by wind erosion in the spring of 1951. Where three years of alfalfa had been included in the crop rotation, the soil lost from the land in potatoes was only 970 pounds per acre. Land cropped to wheat continuously was 4.4 times as erodible as wheat after second-year sweetclover. The yields were 19 bushels an acre for continuous wheat and 45 bushels for wheat following second-year sweetclover.

TERRACES SUPPORT CROPPING IN THE WIND EROSION CONTROL PROGRAM

Uniform distribution of the moisture within a field is important, for it is necessary for development of plant cover. For example, a droughty knoll or slope of only a few acres may start erosion. Once blowing starts, it spreads to or menaces well-watered parts of the same or adjacent fields.

Thus, level terracing[2] (except on heavy soils) and contour tillage are a material support for a cover program. They have increased the soil moisture supply 25 per cent. This type of soil management helps save water for droughty periods. Level-closed-end terraces are of doubtful value on the heavy soils. The infiltration rate of these soils is so low the water might stand in the fields long enough to damage the crops.

Open-end terraces are best where stubble-mulch tillage is used. The most practical terrace interval can be determined by linear spacing of terrace area rather than by vertical spacing. The average distance between terraces on silty clay loam wheatlands in the Plains

[2] Level terraces have the same elevation throughout their entire length.

should be 125 to 150 feet. On typical areas of this kind of soil the vertical interval can range from 0.4 to 1 foot. The height of the terraces should be adjusted accordingly. Where small areas of a field are very uneven, splice terraces should be built if the uneven distance exceeds about 250 feet. Terrace sections should be eliminated where this distance falls below 75 feet, but terraces ending in midfield or abutting the edge of the field should have closed ends.

It sometimes becomes necessary to change the vertical interval within a field. On the High Plains, terraces are designed to retain the water that falls within a given area. A fixed vertical interval on land with slopes of less than 1 per cent causes extremely wide variations to occur in linear spacing where relatively small variations in slope are located. The importance of getting water to all parts of the field makes adjustment of vertical interval and terrace height necessary.

The terrace cross section best suited to wheat farming is low and broad. A broad crown aids the use of machinery in maintaining the terraces, but a properly built wheatland terrace can be cultivated and planted the same as any other part of the field. It can be maintained with one trip of a one-way disk plow around the terrace annually.

Loam soils used for diversified farming should be terraced in the manner described for wheatland The distance between the terraces should be 150 to 200 feet, however. A narrower base may be used, if row-crop production alone is to be practiced on loam soil. But, under semiarid conditions, a terrace base of thirty feet or more is desirable.

WINDBREAKS

Windbreaks can be used to control wind erosion where the rainfall is enough to support trees The utilization of trees as windbreaks in humid areas where wind erosion is a problem is relatively simple. Since moisture is not a limiting factor, trees can be planted in accordance with a standard pattern. However, standard patterns are not always feasible in areas of limited rainfall. Occasionally, the pattern of tree planting in such areas must be made to conform to the topography[3] of the land rather than to a standard pattern. By conforming to the topography, better advantage can be taken of the

[3] Topography is the configuration of a surface, including its relief, the position of its streams, lakes, roads, etc.

limited amount of water available. This plan provides for planting trees in low places where water tends to accumulate during rains. They should be planted in drainage ways and similar places where snow accumulates in the winter.

The principal value of trees in wind-erosion control is in the broader protection they give to cultivated fields. Cultivated fields may start blowing as a result of exposure to dust swept from bare roadways. Windbreaks scattered over a wide area break up the surface wind currents.

Along highways where snowfall is heavy, tree windbreaks should be placed on the lee side (direction wind blows) of the road. Naturally, favorable sites exist along level stretches of the roadway. Places where surface waters collect, stand in ditches, and soak into the soil provide an important additional moisture supply for trees. Other naturally favorable locations occur along drainageways and small lakes in pasture areas along farm roads. Control of erosion by appropriate vegetation may also help to improve conditions for planting on adjacent areas. Sites of this type should be developed with strict regard to the availability of water from the drainage area. In some areas, it may be possible to obtain water for the trees by means of diversion structures.[4]

Species suitable for windbreak plantings include Chinese elm, Russian olive, green ash, cottonwood, and tamarisk. These have proved their hardiness in the Panhandle area.

Temporary protection against rabbit injury is necessary for young trees, which should be protected until they are large enough to withstand attacks. A permanent rabbit guard of wire netting is preferable. The suitability of trees for windbreaks varies with soil type, moisture supply, and other factors. In general, tall-growing trees should stand from eight to ten feet apart in the row, and should be interplanted with more shrublike species.

Wind-tunnel studies show that the sharper the barrier the more complete is the protection provided. Rounded shapes have a lesser influence than narrow vertical shapes. The openness of the foliage of a barrier decreases the degree of protection downwind but extends its zone of influence, however.

In addition to protecting the soil from erosion, windbreaks planted around farmsteads render another valuable service. By reducing

[4] Structures for diverting water around or from specific places.

wind velocities in the winter, they reduce the fuel requirements for the farmer and the feed requirements for the livestock. They may reduce fuel requirements from 25 to 34 per cent, depending on the way the windbreaks are laid out, their height, and the density. Livestock protected by windbreaks require less feed and gain weight more rapidly than those not protected

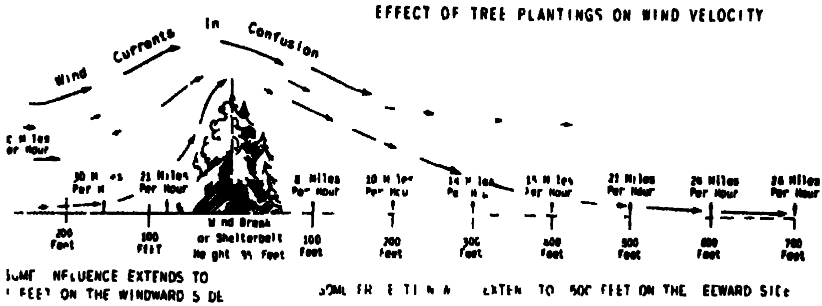


Figure 11-12 Effect of windbreaks on wind velocity (Soil Conservation Service Photo)

TILLAGE AND WIND EROSION CONTROL

The best way to prevent wind erosion is to keep the surface of the ground covered with plants at all time The more often a soil is cultivated and the longer it lies bare, the more apt it is to be damaged by wind erosion

The system that keeps the most residues on the surface is most desirable from the standpoint of erosion control Stubble-mulch[5] tillage makes it possible to carry heavy residues over into the second year This is important in years when crops fail or do not produce enough cover.

Stubble mulch should be left undisturbed until weed growth is sufficient to require cultivation the following spring This is the most effective method of controlling wind erosion and is also satisfactory for wheat production At Amarillo Texas, for an eight-year period, average annual acre yields of wheat were identical for early

[5] Tilling the ground in such way as to leave as much of the crop residue on the surface of the ground as possible

and late fallow The yield in each case was twenty bushels. With late fallow, all the crop residues were left on the surface during the winter and spring months

Standing residues are more effective than plowed residue for controlling wind erosion during the blowing season. This is especially true following years of low crop yields or crop failures Only small amounts of crop residues are produced, but standing residues protect With stubble-mulch tillage following harvest (as practiced with early fallow), some of the effectiveness of the stubble for controlling wind erosion is destroyed

When soil is bare, any tillage that roughens the surface gives temporary protection from erosion, by ridging or clodding the surface soil or by raising subsoil material to the surface Among the implements that have been used for ridging and clodding are the lister, shovel or sweep cultivator, deep furrow drill, spring-tooth harrow, plow, and pocket digger Implements that have been used for bringing subsoil to the surface are the subsoil plow, moldboard plow, lister, disk plow, and grading machine If considerable crop residue is present, blowing can be controlled by subsurface tillage[8] If crop residue is lacking, the land is more likely to blow when subsurface-tilled than when plowed or listed This is because subsurface tillage does not leave a cloddy surface

Shallow tillage of moist soil increases clodding of sandy loams The object of raising heavier soil material from the subsoil is to produce a more cloddy structure in the surface soils Surface soils often become unstable Operations of this character may do permanent good, but because they are costly they should be considered only as a temporary substitute for plant cover

Plant cover serves the same purpose In addition, it provides other advantages, and costs less Plant cover renewed once a year gives more lasting protection than mechanical controls, it aids in maintaining soil fertility, and keeps the rate of moisture absorption at a high level

Tillage methods offer only temporary relief If used, they must be repeated at intervals during the season They are costly In no case should they be substituted for plant cover Once conditions become favorable, either a regular crop or an emergency cover crop should

[8] Subsurface tillage is stirring the subsurface without turning the top soil over, such as with a sweep set to run flat

be started. Tillage practices should be used to the maximum when there is no plant cover.

RECONDITIONING LANDS DAMAGED BY WIND EROSION

The most common effect of wind erosion consists of removing the topsoil to plow depth and piling it up in hummocks or drifts. Many fields are so rough that equipment cannot be driven over them.

The first goal in reconditioning wind-eroded soil is the establishment of plant cover, which must be preceded, where necessary, by leveling. This permits ordinary farming operations and accumulation of moisture for the crop to be grown.

The leveling operation may be carried out by the use of wind intensifiers, drag poles, or tractor and road grader. Gunny sacks filled with sand and placed at different spacings on the crest of dunes are effective wind intensifiers. After the sandbags are in place, channels about three feet wide and four feet deep are dug across the dune. The sand is carried out beyond the crest, and the sandbags are lowered as the wind blows the sand from around them. This method has lowered a dune about two feet during a single storm. It flattens the crest and forms small dunes six to ten feet farther on.

A drag pole, eight by eight inches, of sufficient length to extend down the leeward slope of a dune from the crest to the base is used. It is dragged along the sharp edge at right angles to the crest. A tractor and road grader may be used to level up the field directly or to cut wind channels in the dunes parallel to the direction of the wind. One or more turns over the highest points removes enough soil, thus giving the wind a chance to continue the process. A twenty foot dune, prepared for wind-blast action by this method, was leveled to five feet during a six-month period. It was put in condition for planting.

Broomcorn and Sudangrass are satisfactory plants for use in stabilizing dunes, because they are more resistant to wind action than most crops.

WIND EROSION CONTROL ON MUCK LAND

Wind causes direct soil loss on muck land and may cause widespread damage to growing crops. Some of the major damage caused by this type of wind erosion is located in Michigan, New York, and

California. In Michigan and New York, the major damage occurs in late spring. During this period, the wind picks up large quantities of the finely divided material, as well as sharp pieces of muck and wood, and hurls these against tender stems of the young vegetable plants. A few days of active blowing may be enough to cut off the above-ground growth of young plants.

The critical period in the San Francisco Bay area in California is April, May, and June. Here the major damage is done to lands planted to asparagus.

The use of windbreaks is the most effective means of controlling the wind velocity in muck areas. They should be placed in rows at right angles to the direction of the prevailing wind.

Tree planting is relatively cheap and easy. Dense masses of trees deflect the wind currents upward and off the surface of the land. For each foot of tree height, eight to sixteen feet of protection on the leeward side is obtained. Three rows of trees with a row of taller-growing species in the center serve to assist the upward deflection. Thus, by proper selection and spacing of trees, areas can be made relatively free from wind damage. Decreasing the wind velocity prevents soil blowing. Hardy, long-lived, tall- and rapid-growing trees should be selected. Low-growing shrub hedges are not desirable or effective.

The outside boundaries of the area are determined, then the rows of the tallest varieties are planted. The main defense lines should consist of three rows at least eight feet apart—the trees should be six feet apart in the row. Crop-row spacings should be adjusted to the type of cultivating equipment used on the farm and the tallest-growing variety planted in the middle.

Secondary defense lines should cross the fields, every 330 to 660 feet, at right angles to the main defense strips. The rows may be single or double, and should be six feet apart with the trees four to five feet apart in the row.

Trees should not be planted nearer than twenty feet to roads or near tile lines. Full use cannot be made of muck-land soils until tree plantings are established to break the wind.

Fall-seeded rye may be used as a temporary windbreak under certain conditions. A few rows of fall-seeded rye make enough growth by late May or early June to protect the soil. A few rows of rye seeded immediately adjacent to a row of newly started willows make an effective windbreak. The rye should be on the windward

side of the permanent windbreak. Spring-seeded oats or barley handled in the manner indicated for rye may be used where rye was not started the previous fall. Oats and barley may not grow as high as rye, but they may make a denser windbreak at the immediate surface of the muck. The use of these grains, or wheat, greatly improves the effectiveness of newly started windbreaks.

Oats may be used in single rows between rows of onions seeded in the usual manner. The oat rows may be placed from six to fourteen inches apart.

The windbreak on muck soils protects or checks the velocity of the wind for a distance to the leeward of about twenty times the height of the windbreak.

Cover crops are highly desirable when there is any likelihood of blowing during winter. A cover crop of rye or wheat, planted in pure stand or mixed with oats or barley, covers the soil completely. It protects the soil from the wind.

In addition to providing winter protection, the roots of a cover crop, especially of fall grain, when plowed under for the succeeding crop hold the muck. Moreover, the fresh organic matter provided by the cover-crop materials tends to increase the size of the muck granules. These larger granules are not so easily moved by the wind.

The soils of the Great Plains have been found to be highly erodible by wind when 50 per cent of the total material is less than two millimeters in diameter. By comparison, an average of 74 per cent of the peat soil materials is less than this size. Too, the muck material weighs only about one third that of sand, which means that muck soils blow easily.

In the Delta area of the interior valley of central California, erosion is caused by winds from the Pacific Ocean. Cool moist winds from the Pacific blow across the ground surface, which is upset by the upward movement of heated air rising from the dark ground surface of the muck lands. The result is a turbulent mixing process. The extremes of heat exchange result in the formation of rotating columns of air masses that funnel the lighter heated air from near the ground surface to higher elevations.

Approximately 40 per cent of the dust movement in this air is due to direct blowing of the wind, 30 per cent is due to dust whirls, and the other 30 per cent is due to factors related to crop culture.

Satisfactory methods of wind control have been developed for some of the conditions prevailing in the San Francisco Bay area.

They reduce the direct and rotational wind force arising from the bare cultivated ground surface The period of highest wind movement occurs during April to July The methods include the use of protective mulches, residues, stripcropping, or wind barriers in the form of trees, shrubs, or crops Farmers, however, are reluctant to adopt them, because they involve the use of new types of farm machinery and the farmers don't want to discard their old machinery for new

Adoption of crop residues as a protective surface cover requires changes in cultivating equipment A modified system of stripcropping could be carried out in conjunction with the growing of asparagus—the principal crop grown Such a system should provide either a live or dormant crop that would grow higher than the crowns of the asparagus ridges during the period of April through June

Questions

1 Where is wind erosion most common? Why is wind erosion so harmful?
2 Why are the first dust storms more harmful than later ones?
3. What is the key to wind erosion control? What is the solution?
4 Why is ridging the land not a permanent solution to wind erosion?
5 How does plant cover prevent wind erosion?
6 Why do sandy soils erode more easily than heavier soils?
7. How do clay soils differ from sandy soils when being eroded by wind?
8 Why is high stubble more effective than low stubble in preventing soil blowing?
9. What is meant by stubble mulch farming? How does it control soil blowing?
10. How does stripcropping help stop soil blowing? Why is stripcropping less satisfactory on clay soils than on sands?
11 How do wind breaks prevent soil blowing? For what distances are they effective? How should they be put out?
12 Under what conditions should plowing and listing be used in a wind erosion control program?
13. How does wind erosion damage in muck land differ from that on wheat land?
14 What is the proper procedure for stabilizing dune sand?

15

Mulch Farming for Row Crops

On a few farms in the Corn Belt and other parts of the country a new method that bids fair to alter our method of growing row crops is emerging. Used primarily on corn to date, it is based on sound and well proved principles that all but eliminate erosion. It also conserves water, increases crop yields, lowers crop production costs, and improves the soil all at the same time.

All versions of the new method have the same foundation. It is the way crop residues and other organic materials are being managed. Other building blocks appear in the form of wider row spacings, increased number of plants per acre, liberal use of fertilizer and less disturbance of the soil.

The new method of farming utilizes plant cover. Some use crop residues as mulch on the surface of the ground, others use wide rows. Sod crops are grown on the strips between the corn rows during the corn-growing season. The mulch or sod crops protect the soil against the blasting action of falling raindrops. It also gets more of the rain water into the ground.

Protecting the surface preserves the physical structure of the soil and holds to a minimum the loss of organic matter and plant nutrients by erosion. The increased amount of soil moisture made available by this process assures larger yields of the row crops and a greater total yield where the sod strips are used between the rows of cultivated crops. The outstanding feature of this method is that land can be heavily cropped every year. If need be, the same crop can be used year after year, improving the soil at the same time.

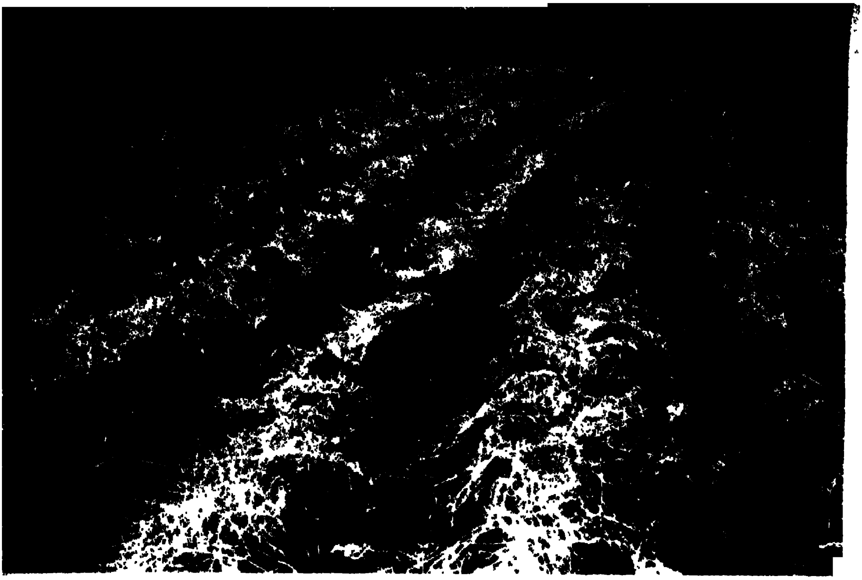


Figure 15-1. Corn planted on a contour in Illinois, in a mulch of alfalfa and bromegrass. The photograph shows the field after a heavy rain. (International Harvester Company Photo)

One variation of the new method of growing row crops is illustrated by the success of Dr. George Scarseth (formerly Head of the Agronomy Department, Purdue University, now Director of the American Farm Research Association) in growing corn on a rundown Indiana farm. The farm in Tippecanoe County, Indiana, that Dr. Scarseth bought in 1950 made only 25 bushels of corn per acre that year. The farm had not yielded more than 30 bushels an acre for the previous ten years.

On May 24, 1951, Dr. Scarseth planted corn with a mulch planter. There was no plowing, disking, or other soil preparations—the corn was planted through a mulch of weeds and cornstalks.

One kernel was dropped every eight to ten inches in forty-inch rows. This gave a stand of 17,000 stalks per acre. The planter placed fertilizer at two depths: 300 pounds of 10-10-10 in a split band, three inches deep in the row, to get the seedlings off to a fast start ahead of the weeds; and 800 pounds of 10-10-10 in a band, nine inches deep, to feed the corn as it grew.

Weeds were controlled but not killed by two shallow cultivations. To be certain there was plenty of nitrogen to grow both corn and weeds, Dr. Scarseth side-dressed the crop with 200 pounds of ammonium nitrate per acre. This was placed six inches deep, a foot

from one side of the row. The nitrogen was applied July 6, the time of the second and last cultivation.

Rainfall was ample early in the season, but August was very dry. There was a bad Helminthosporium infestation in September. Test rows in the field were given less than the full fertilizer treatment, and showed the need of enough plant food to do a complete job. Corn must get off to a quick, profitable build-up in yield Table 13 makes this plain

TABLE 13

PER ACRE FERTILIZER TREATMENT YIELD PROFIT

Amount of Fertilizer	*Bushel*	*Fertilizer Cost*	*Production Cost*	*Profit or Loss*
No fertilizer	2.5	$	$38.45	$34.70
300 lbs 10-10-10 in row	30.0	8.50	46.05	1.95
300 lbs 10-10-10 in row 800 lbs 10-10-10 at 9 inch depth	5[illegible]	38.17	76.57	4.18
1,100 lbs 10-10-10 plus 200 lbs ammonium nitrate side dressing	155	46.6[illegible]	85.07	103.18

Where no fertilizer was applied there was a loss of $34.70 an acre The use of 300 pounds of 10-10-10 per acre didn't quite break even Increasing the fertilizer rate to 1,100 pounds of 10-10-10 (300 pounds in the row and 800 at nine inch depth) produced a profit, but a small one A sizable profit was not obtained until the fertilizer was increased to 1,100 pounds of 10-10-10 plus 200 pounds of ammonium nitrate as side dressing Production costs ran up to $85.07 an acre, but the profit was $103.18

This method of growing corn is based on well established experimental findings It is well known that mulches get more water into the ground, hold the moisture better, and prevent erosion Plenty of plant food was applied to meet the requirements of both weeds and corn Sufficient quantities of plant nutrients were added to grow 150 bushels of corn per acre under favorable conditions The corn was planted thick enough to get 17,000 plants per acre This was needed to produce 100 or more bushels corn per acre Cultivation was held to a minimum in order to hold down erosion and to preserve soil tilth.

The soil on this farm was protected a full twelve months of the year Stalks, shredded when the corn was picked, provided a mulch

cover during the winter, so the mulch planter did not disturb this cover. Two light cultivations with disks knocked down and stunted the weeds but did not kill them. Weed growth in the spring and early summer, plus stalk mulch, held the soil. The plant cover prevented erosion despite a near cloudburst that badly eroded nearby clean cultivated fields.

Clean cultivation is a poor practice. Weeds, fed enough nutrients so that they won't rob the crop, make good cover. They can be as important as clover or grass in building fertility and preventing erosion, by supplying organic matter, improving soil tilth, and providing cover. Weeds did not hurt the corn yields in this field, because the corn plants, stimulated by plenty of plant food, outgrew and

Figure 15 2 Mulch planter. Mulch planting produces cultivated row crops under soil improving rather than soil depleting conditions by combining two beneficial practices, namely (1) maintaining a mulch on top of the ground to retard erosion from wind and water, maintaining open surface soil structure, increasing water intake, and making maximum use of crop residues to improve soil tilth and fertility, and (2) making more efficient use of soil moisture and chemical fertilizers to increase crop yields, resulting in even greater volumes of organic matter for further improvement of soil tilth and fertility. (International Harvester Company Photo)

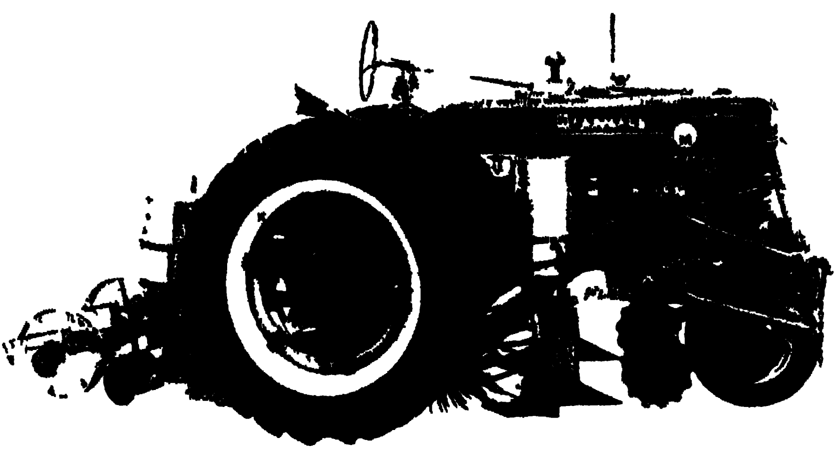


Figure 15 3 Planting with mulch planter in Illinois Note the heavy mulch of chopped stubble on the surface of the ground between the rows (International Harvester Company Photo)

finally shaded the weeds A thick stand of corn is needed to do this

In test rows 1,100 pounds of 10-10-10 produced only 59.5 bushels of corn There wasn't enough nitrogen for both weeds and corn The sidedressing of an extra 66 pounds of nitrogen boosted corn yields to 125.5 bushels an acre

Plant nutrient used by weeds is stored capital if it is not lost by erosion The capital is in the form of organic matter improved tilth, and fertility and will show up in extra corn later

This method with some modifications produced an average of 98.9 bushels of corn per acre in 1953 the growing season of which was dry and hot In addition the corn took just three hours of man and tractor time (the average time is ten hours) per acre thus allowing a saving of $28.00 per acre in man machine costs alone

ADJUST FERTILIZER AND PLANTS TO MOISTURE

This new method of growing corn is based on the assumption that enough fertilizer must be used to feed the largest number of plants the available moisture will support This is the only way to get top yields

Today in the Corn Belt and in irrigated sections the recommendation is around 16,000 to 20,000 plants per acre The number of

plants to use depends on the soil, fertilization, and other factors. This is also true for the Northern states, where single-ear hybrids are used. In the South, where two-ear hybrids are used, the range is from 10,000 to 14,000 plants per acre. In the Great Plains, it runs from 4,000 to 6,000.

WIDE ROW SPACINGS

Wide corn rows—60 inches, 72 inches, and 80 inches—are gaining in popularity. By spacing the plants close enough together in the rows, wide rows produce almost as high yields as 40-inch rows. In addition, they allow the production of sod crops in the middles during the corn-growing season. Robert Arnold of Greencastle, Indiana, harvested 75 bushels of corn per acre in 1953 from single rows 80 inches apart. He also grew an excellent pasture crop in the middles for his hogs. Ted Funk, McLean County, Illinois, planted 200 acres of corn—a row every 60 inches—which averaged 90 bushels per acre. And he got a good stand of legume-grass seeded in the middles.

Funk's Research Acres in McLean County, Illinois, obtained 122 bushels of corn per acre in 40-inch rows, with every third row missing, 125 bushels per acre, with corn in single 60-inch rows, and 99 bushels per acre, with corn in single rows 80 inches wide

In two years of tests, single 60 inch rows produced more than corn planted in 40-inch rows The 80 inch rows at Research Acres showed about a 15 per cent decrease in yield compared with customary 40-inch planting.

WIDE ROWS GIVE BETTER STANDS OF LEGUMES

Yields are only a part of the story the grass-legume seedings showed up well. Atlantic alfalfa, Kenland red clover, ladino clover, and brome were seeded in the middles The stand of grass-legumes in 1953 in the 60- and 80-inch corn middles was better than where seeded in oats or wheat.

Despite a very dry August, the summer seeding of grass-legume in wide-row corn was about as good as the seeding with oats, thus making corn superior to oats Corn produces about a hundred bushels per acre and oats only about fifty. In addition, the oats frequently lodge (fall down) because of high fertility. When oats

lodge, the grass-legume seeding is smothered out. By eliminating the oats, a corn-legume-corn-legume rotation can be followed, allowing half of the land to be in corn and half in legumes. This gives a higher cash return and plenty of legumes for a livestock program.

PRESENT FARM MACHINERY INADEQUATE

Farm machinery in the Corn Belt was designed for use on 40-inch rows and clean cultivation, and is not suitable for use with wide rows. The mulch planter is solving the plowing and planting problem. The mulch planter and the use of weed killers are practically eliminating the need for cultivation. The corn pickers and certain other types of machinery need to be redesigned to meet the needs of the new method of growing corn.

NITRO-GRASS ROTATION FOR CORN

The Illinois Agricultural Experiment Station is developing one modification of this method of growing corn: It uses grass and nitrogen fertilizer instead of legumes for soil improvement in cropping systems. This is called "nitro-grass" rotation, which produces maximum corn yields and gives complete protection against soil erosion.

CHEAP NITROGEN FORCES CHANGE

The use of cheap nitrogen assures significant changes in corn production practices. The legume program for grain systems of farming has limitations imposed by the nature of the program. Well-managed Corn Belt farms are so productive that yields are held back. Legumes do not provide enough nitrogen for the high yields made possible by the rotation.

Ordinarily half of the land remains bare and subject to erosion because it is in corn and beans. Thus, erosion control is only partially achieved, because the organic matter content cannot be maintained. Getting a stand of legumes is becoming most difficult.

Some of the limitations of the legume system can be eliminated by use of cheap nitrogen. The cheap nitrogen helps the legume program, especially on second-year corn, wheat, or oats, and on first-year corn when the legume does not develop fully or fails.

CORN BELT IS GRASS COUNTRY

The Corn Belt was grass country. Thousands of years ago, the grasses in the native prairie vegetation took over and reduced the native legume population to around 3 per cent. As soon as the legumes had built up enough nitrogen in the humus to meet the requirements of the grasses, they were crowded out.

Except for nitrogen fixation, grasses are far better than legumes for many purposes. Grass pastures do not cause bloat in cattle; pure legume pastures do. Grasses form better, tougher sods; legumes usually form relatively poorer sods. Sweet clover and soybeans actually encourage soil erosion. Grasses form a better granular or crumb structure in soils. Stands of grasses are, in general, more easily obtained than stands of legumes.

Most important in the Corn Belt, grasses can be fall-planted and amount to something for late fall, winter, and spring cover and pasture. Except for vetch, which is uncertain, legumes cannot be fall planted and used for this purpose in the Corn Belt.

These are the reasons why big changes in corn production methods in the Corn Belt may be expected. With all these advantages in favor of grasses, there appears to be no good reason why grass and nitrogen cannot supplant the legumes. This is especially true, since nitrogen makes grass approach legumes in protein composition. We are concerned here only with legumes used in grain rotations, primarily for soil improvement.

More study of the effect of "nitro-grass" rotation on the management and nitrogen fertilization of the grass is needed before specific recommendations can be worked out. Growing grass without nitrogen and utilizing the residue for corn can reduce yields, rather than increase them. The grass, in decomposing, uses nitrogen needed for corn, but the result with nitrogen-treated grass can be different.

With no knowledge of how to handle the grass (rye was planted between the rows in the middle of August), the Illinois Agricultural Experiment Station obtained 89 bushels of corn per acre annually. The study lasted four years. Each year, enough nitrogen was used for the corn and to decompose the rye crop, too.

RYE IS SHREDDED

The waist-high green rye was shredded at corn planting time. The corn was planted and fertilized in one operation, with the

mulch planter, and most of the chopped rye remained on the surface as mulch.

In addition to producing an average of 89 bushels of corn per acre, this practice increased the organic matter supply of the soil. It also practically eliminated erosion and did improve the structure of the soil. A mulch was provided all summer, and this increased the biological activity of the soil to an all-time high. Legume rotations only partially achieve these objectives.

The only concern is that perhaps some of the organic matter could be used more economically. It may be better to use some of it as feed for livestock, rather than returning all of it to the soil. Eight crops (one of corn and one of rye each year) in four years will produce a lot of organic matter. It may not all be needed for mulch cover, so perhaps the rye could be used more economically for moderate grazing in the fall and spring. It may even be mowed early for grass silage. The shredded corn stalks should provide adequate cover and erosion protection. The kind of grass to use and how it should be handled needs further study. Experience indicates some such nitro-grass program holds the key to high production. High yields mean low costs per bushel.

GROW CORN OFTENER

Such a cropping system makes it possible to grow corn every year on the same field, improves the soil, and increases the yield at the same time. There is nothing to indicate this practice will lead to increased difficulties from insects and diseases.

By using such systems, corn can be grown oftener and more profitably. If the grass can be used as a crop, so much the better. Soil organic matter maintenance, and even its increase, will still be achieved. With two crops a year, competition from pasture-grown beef can be better met. Returns per acre can be even higher than from just 90- to 100-bushel corn. In addition, of course, practically complete soil erosion control is thrown in as a dividend.

ADD INSECTICIDES TO FERTILIZER

Another noteworthy development in this cornfield improvement is the use of fertilizer as a "carrier" of insecticides. Rootworms, wireworms, cutworms, and beetles can be controlled for $2.00 or $3.00 or less per acre, by using fertilizer as insecticide carriers. In Kentucky, fertilizer-mixed aldrin (one pound per acre) or chlor-

dane (two pounds per acre) boosted corn yields as much as nineteen bushels an acre This increase was obtained, even though the check plots showed little or no injury from corn rootworms or other insects The corn plants also were faster growing and earlier tasseling At these low rates of use, there is nothing to lose and a lot to gain, even if the Southern rootworm does not attack your field

SEED WHEAT IN CORN

The Ohio Agricultural Experiment Station is finding it profitable to seed wheat in unharvested corn The corn is planted in 70-inch rows, and the wheat is seeded in the wide middles at the fly free date This practice delays corn harvesting until the corn crop is in condition for it and also provides a longer growing season for the wheat

Most of the loss in yield caused by wide row spacing is made up by utilizing more of the growing season The average result should

Figure 15 4 Interplanting between wide rows of corn Vetch and rye grass in 63 inch rows at Wooster Ohio The vetch and ryegrass were seeded in late June 1953, the photograph was taken about August 15 1953 (Ohio Agricultural Experiment Station Photo)

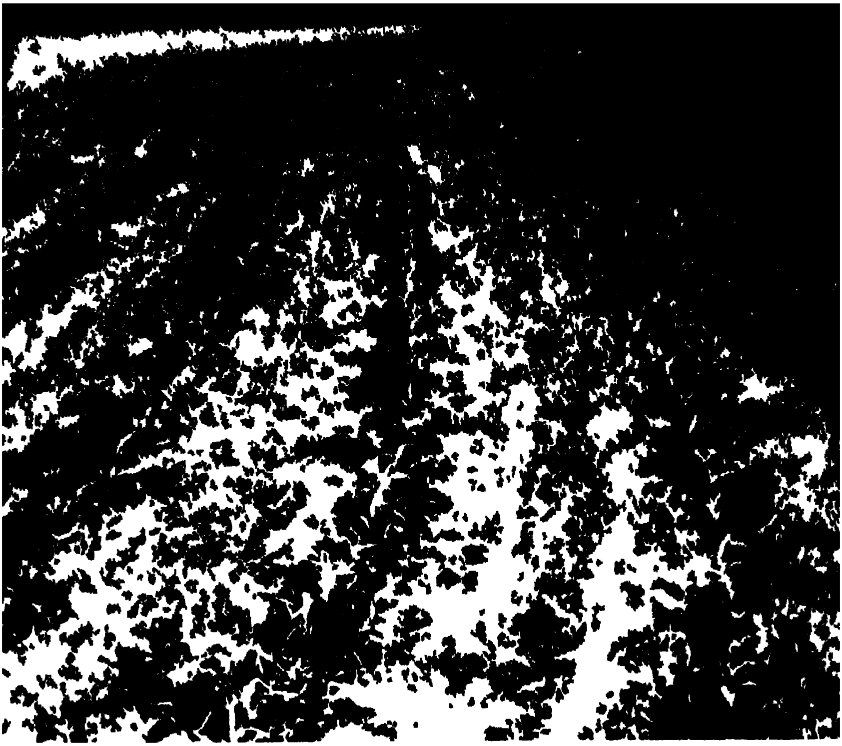


Figure 15.5 Corn planted in alfalfa sod in Illinois. The alfalfa sod protects the soil from erosion, increases the amount of rainwater that enters the ground and improves corn yields. (International Harvester Company Photo)

be about three bushels less of corn, three bushels more wheat, better quality of both crops, and orderly sequence in fall farm jobs.

The farmer who does not sow wheat after corn could profit by planting cover or meadow crops directly in the growing corn. Experiments with row space widths at Wooster suggest the idea that such a system can be practical, or at least as practical as any system that depends on summer seeding of small-seeded crops.

MULCH INCREASES CORN YIELD

Corn land at Wooster, Ohio, mulched in 1953 with ten tons of manure per acre produced nearly eight bushels of corn per acre more than similar land with an equal amount of manure plowed down. In 1951 the increase was eleven bushels, in 1952 it was ten

bushels. The increase from using a two-ton mulch of straw in the summer of 1953 was sixteen bushels per acre.

Soil moisture in August, 1953, was 3 per cent higher under manure mulch and 4 per cent higher under straw mulch than in unmulched soil. Four farmers who tried the practice in 1953 got increases in yields of six to nineteen bushels.

The water-saving capacity of mulching was again shown on runoff plots at Wooster in 1953. Unmulched soil lost more than one-third of the rainfall by runoff, but the manured mulched plot lost only a small percentage. It is the bedding in the manure that does the job: The more bedding in the manure the more efficient mulch it makes.

ADEQUATE USE OF FERTILIZER POINTS WAY TO HIGHER PRODUCTION

The science and practice of using commercial fertilizers are undergoing radical changes. The possibilities for increasing farm efficiency by eliminating low soil fertility are just now being appreciated. There has been recent research on the application of required nutrients that showed it is possible to produce high yields on poor soils in favorable seasons.

By using appropriate soil-building programs, much abandoned land is being made more productive than when it was first cultivated. Some fields that were once considered suitable only for trees or rough pasture are now producing profitable yields of corn and other crops. The wide difference in the original productiveness of virgin soils has been almost eliminated in favorable seasons by use of fertilizer.

ORGANIC MATTER IMPORTANT

Our past crop yields have been closely associated with the quantity of organic matter in soils. Probably over 95 per cent of the nitrogen and over 50 per cent of the phosphorus absorbed by crops on unfertilized soil come from organic matter. With soils high in humus, and conditions ideal for organic matter breakdown, yields are usually high, but in excessively dry or wet seasons, these nutrients are not released. Yields are reduced.

Crop rotations including legumes have been widely used as a means of restoring soil nitrogen and organic matter. The value of

these legumes has been almost universally accepted Yet under practical farm conditions they actually have added only limited amounts of nitrogen and hidden erosion losses Legumes add nitrogen and furnish soil cover, but they remove more minerals from the soil than do grain crops This is particularly true when only the grain is removed

In Missouri, sixty five years of different cropping systems show soil changes from different crop sequences and soil treatments Where legumes and grasses were included in crop rotations on unfertilized soil, the soil now contains less phosphorus potassium, calcium and magnesium than where corn or wheat was grown continuously The first cropping system that failed was continuous clover grown without fertilizer After fifteen years this system was abandoned This crop exhausted the mineral nutrients of the soil, which were removed in the hay

Legumes are grown as green manure crops for soil improvement on many farms However where livestock is produced, the use of legumes primarily for soil improvement is more an ideal than a reality Most legumes are used as livestock feed It is reasoned that where manure is returned the soil is benefited In some regions winters are so severe that barn feeding is required However, the amount of manure returned is too low to be of much value In much of the southern two thirds of the United States most winter feeding is done in pastures There is little manure to be returned to cultivated fields

Experiments show that legumes do not furnish sufficient nitrogen for optimum corn yields The addition of chemical nitrogen when legumes are turned under has given profitable increases in yield

TABLE 14

YIELDS OF CORN FOLLOWING LEGUMES WITH AND WITHOUT SUPPLEMENTAL NITROGEN* THREE YEAR AVERAGE PUTNAM SILT LOAM

Corn Following	*Yield* *Without Nitrogen* (Bushels)	*60 Pounds Nitrogen* (Bushels)
Red clover	74	101
Sweet clover	[illegible]	10
Lespedeza	85	[illegible]
Soybeans	87	110
Timothy	4	95

* Mineral treatments added in quantities to remove them as limiting factors in production

Chemical nitrogen is being used in ever increasing quantities. Consequently, the need for additional minerals to maintain a proper balance is a necessity for maximum yields of quality crops.

SOIL TESTS SHOW NUTRIENT NEEDS

As soils declined in fertility, small additions of phosphates and mixed fertilizers were applied to improve yields. For years both experiments and farm practice attempted to determine the minimum quantities of fertilizer that would give a profitable yield. In only a few cases, the quantity of nutrients added was large enough to replace that which was removed in crops. Losses by erosion also had to be replaced, consequently soil fertility continued to decline.

It formerly was possible to determine nutrients needed for a given soil type through field experiments. But past management has changed soil nutrient levels so greatly that more variations may be found on adjoining farms with similar soils than between soils with widely different characteristics. Without soil tests it is not possible to determine the limiting factors in plant growth.

Addition of plant nutrients in fertilizers to bring a low fertility soil up to high fertility may involve a cost nearly equal to the value of the land. In the interest of farm efficiency and best plant growth only those nutrients that are deficient should be added. Experiments have shown that addition of a nutrient already present in adequate amounts may depress rather than benefit yields and quality.

INTERPRETING SOIL TEST RESULTS

Organic matter is about 5 per cent nitrogen. Under conditions in the Corn Belt from 4 to 6 per cent of this nitrogen is released on sandy soils. Silt loams release from 2 to 3 per cent and loams about 1¼ to 1½ per cent. If a soil analysis shows 2 per cent organic matter, the surface seven inches (2,000,000 pounds) would contain 40,000 pounds. Considering a content of 5 per cent nitrogen this soil would contain 2,000 pounds of nitrogen, or 1,000 pounds for each 1 per cent organic matter. If the soil was a silt loam and from 2 to 3 per cent of the nitrogen were released annually, then this surface soil could provide a corn crop with from forty to sixty pounds of nitrogen. This would produce thirty to forty bushels per acre.

These methods of calculation have given good checks with field experiments. The high levels of release are obtained in good seasons

and the low levels in excessively wet or dry years. A summary of 208 corn fertilizer experiments conducted in all parts of Missouri showed that nitrogen applied according to soil tests increased yields from 56.9 to 97.3 bushels. This was an increase in yield of 1 bushel for each 2.2 pounds of nitrogen added.

Small grains make most of their growth during the cooler season, when organic matter breakdown is slower. Satisfactory results have been obtained using values for release of nitrogen from the soil equal to one-half that used for corn.

Phosphorus becomes a limiting element when levels of available nitrogen are increased. Field results indicate that for maximum yields of wheat and clover, the soil should show a reserve of near 200 pounds of phosphorus per acre. For corn, soybeans, and oats, it should be at least 100 pounds.

Potash needs are increased as we remove more legumes. Best results with corn and clover have been obtained with tests showing potassium levels of nearly 300 pounds per acre. A 200-pound level appears adequate for soybeans, wheat, and oats. Recent experimental work suggests it may be desirable to add much greater quantities of potassium than these, except on clay soils.

There are indications that soil tests may be of more value in determining when a soil contains sufficient lime than in determining the amount to apply. Recent tests show that some soils have been overlimed, creating potassium and boron deficiencies. Where high calcium liming materials have been used, magnesium is becoming a limiting element. Dolomitic limestone is not effective if soils are near to neutral. Soluble magnesium compounds must be supplied to correct deficiencies. Soil tests for determining the liming status of the soil are probably the most dependable of all in use.

GOOD SOIL SAMPLES ESSENTIAL

Soil testing still requires some checking with field experiments. Its value is attested by the number of tests being made in all parts of the country and the results accomplished on farms. The weakest link in the soil testing program is poor samples. Too many samples are inadequate, or fail to be representative of the area tested. A poor sample can result in improper diagnosis of nutrient reserves, thus causing improper treatment. For best results, a composite sample of at least six borings should be taken on each five acres (smaller

areas on fields of highly variable soils) The average results from all samples of a field are considered in determining the soil treatment program

ADEQUATE NUTRIENTS REDUCE SEASONAL HAZARDS

Interest in adequate fertilization is the highest in history, but the dread of losing both crop and fertilizer in unfavorable seasons persists. In   , some areas of Missouri experienced the heaviest rainfall on record The State Experiment Station found that where nitrogen was plowed down and minerals had been provided, the corn outgrew grass and weeds The added nitrogen, substituted for that which is normally provided by organic matter, nourished the plants well enough so that the yields were well above average

The seasons of   and   were extremely dry The favorable response in these years dispelled the fear of losses in dry seasons It encouraged the use of soil testing and the application of fertilizer to provide adequate nutrient reserves For example, where moisture was too short to produce corn grain, adequate nutrients in many cases produced enough forage for winter feed

In a corn experiment at Columbia in 1952 adequate fertility made the difference between profit and loss Only 2½ inches of rain fell from July 3 to August 8, and the average maximum temperature was 91 degrees Where no nitrogen was used, the highest corn yield was 54 bushels (This was obtained with a thin stand)

Where the corn population was increased, yields declined Where fifty pounds of nitrogen were plowed down, the highest yield (61 6 bushels) was secured with a population of 11,000 plants With thicker planting, the yields again went down The addition of 120 pounds of nitrogen gave the highest yield, which was 86 2 bushels from 14,000 plants But where 250 pounds of nitrogen were used, the high yield was 97 1 bushels from a stand of 17,000 plants per acre Under these conditions of short rainfall, the heavier rates of planting decreased yields only where there was a shortage of nitrogen. Providing plenty of plant food made a limited supply of moisture more effective.

RESIDUAL EFFECT OF FERTILIZER

In the past, the entire cost of fertilizer treatment has been charged to the crop treated. With heavier fertilization, residual effects are

striking. Where nitrogen was applied to corn at rates of 200 pounds, the increase in yield of the following wheat crop was enough to pay for the nitrogen. The increase in corn yield was net profit. Similar residual responses were secured with oats following corn when fertilizer was used according to soil tests.

TABLE 15

RATE OF APPLICATION AND RESIDUAL EFFECT OF NITROGEN

	Yields per Acre	
Nitrogen Applied	*Corn* *2-Year Average* (Bushels)	*Wheat* *1-Year Average* (Bushels)
0	86.[illegible]	15.[illegible]
3[illegible]	95	18.0
6[illegible]	10[illegible]	[illegible]
1[illegible]	114.5	[illegible].7
[illegible]00	116.7	28.0

Soil limed to pH [illegible], 2000 pounds rock phosphate [illegible] 150 pounds on corn and [illegible]00 pounds on wheat.

FERTILIZE BY PRESCRIPTION

The University of Wisconsin has developed a method of fertilizing crops by prescription. The way such prescriptions are written is relatively simple. It is based on the fact plants can get certain percentages of nitrogen, phosphorus and potassium from the soil, manure and fertilizer. These percentages are given for corn in Table 16.

TABLE 1[illegible]

ESTIMATED PERCENTAGE OF THE AMOUNT OF NITROGEN, PHOSPHORUS AND POTASSIUM PRESENT IN AVAILABLE FORM IN SOIL AND APPLIED AS MANURE AND FERTILIZER THAT MAY BE OBTAINED BY A CROP LIKE CORN DURING ONE SEASON

Source of N, P and K	*Percentage Obtained by Crop During One Season*		
	N	*P*	*K*
Soil (Available Present)	40	40	40
Manure (Total Present)	30	30	50
Fertilizer (Available Present)	60	3[illegible]	50

A 100 bushel crop of corn requires 150 pounds of nitrogen. On the basis of the estimate, it can get only 40 per cent or 80 pounds from a soil that contains 200 pounds per acre of available nitrogen. The 70-pound difference will have to come from manure and or

fertilizer. Only a portion of that applied is available, as indicated in the tabulation above. Consequently, appropriate calculations need to be made in writing the fertilizer prescription for nitrogen, phosphorus, and potassium.

Crop composition varies considerably, but for purposes of these calculations, the average amounts of plant foods contained in the tops and roots of the crop at the stage of maximum uptake suffice. The amounts of nitrogen, phosphorus, and potassium used for three crops under consideration are given in Table 17.

TABLE 17

POUNDS PER ACRE OF NITROGEN, PHOSPHORUS, AND POTASSIUM IN CORN, SUGAR BEETS, AND POTATOES AT YIELDS INDICATED

Crop	Acre Yield	Nitrogen (N)	Phosphorus (as P_2O_5)	Potassium (as K_2O)
		Pounds per Acre in Crop		
Corn	100 Bushels	150	60	120
Sugar Beets	20 Tons	155	60	195
Potatoes	500 Bushels	210	70	290

The calculations involved for writing the fertilizer prescription for any particular field are relatively simple. This is illustrated by the following example, where a prescription for 100-bushel yield of corn is given.

Suppose the soil test shows pounds per acre of available nutrients as follows:

Nitrogen —200 (N)
Phosphorus 35 (P) or 80 when converted to fertilizer phosphate (P_2O_5)
Potassium 125 (K) or 150 when converted to fertilizer potash (K_2O)

Enter the results of the soil test figures for nitrogen (N), phosphate (P_2O_5), and potash (K_2O) in a tabulation as shown in Table 18. Calculate (using percentages above) the amounts the crop will actually get from the soil. Estimate and list the amounts of manure and/or fertilizer that appear to be needed. They should give approximately the amounts of nutrients required for the 100-bushel yield.

The figures for nutrients thus supplied are next entered. Then the respective amounts obtained from the percentages in Table 18 the first crop can get are entered. The total amount the crop can get is next determined. If this total is close to what is used, the job of

TABLE 18

FORMULATION OF FERTILIZER PRESCRIPTION ON BASIS OF SOIL TESTS AND MANURE APPLIED FOR 100-BUSHEL CORN

Source of Nutrient Element	*Pounds Nitrogen*		*Pounds Phosphorus*		*Pounds Potash*	
	Present	*Crop Gets*	*Present*	*Crop Gets*	*Present*	*Crop Gets*
Soil (Available)	200	40% or 80	80	40% or 32	150	40% or 60
275 Lbs. Ammonium Nitrate	90	60% or 54	..	.. ....	..	.. .. .
400 Lbs. 3-9-18	12	60% or 7	36	30% or 11	73	50% or 36
400 Lbs. 4-16-16	16	60% or 10	64	30% or 19	64	50% or 32
Totals Crop May Get	..	151	..	62	..	128
Totals Needed	..	150	..	60	..	120

writing the prescription or formula for the 100-bushel crop is completed.

In 1952, soil samples were collected from 173 fields in ten southern Wisconsin counties and were analyzed for *p*H, available nitrogen, phosphorus, and potassium. Fertilizer prescriptions were then written for individual fields, using the method described above. In addition to soil test results, the amount of manure applied and crop to be plowed under were taken into consideration.

Corn was to be drilled or hill dropped in order to have 17,000 plants per acre. Cultivation was to be shallow, with only one or two cultivations, thus preventing root pruning.

Yield results were obtained by harvesting four 50-foot rows. One row was in each quarter of the field. A composite sample of twelve ears was taken for moisture determination and dried in the oven. Yields were then calculated to a 15 per cent moisture basis. Accurate records were obtained from 173 fields on 102 farms. The yield data are given in Table 19.

TABLE 19

YIELDS OF CORN IN 1952 FERTILIZED IN ACCORDANCE WITH PRESCRIPTIONS FOR 100-BUSHEL YIELD, ARRANGED ACCORDING TO POPULATION

Yield Ranges (bushels per acre)	*Number of Fields in Each Range*	*Average Yield for Each Range* (bushels per acre)	*Average Corn Population* (stalks per acre)
Under 100	15	92	13,370
100 to 110	18	106	13,790
110 to 120	31	116	14,280
120 to 130	40	124	15,200
130 to 140	38	134	15,420
140 to 150	25	144	15,990
Over 150	6	155	16,560

Total number of fields: 173. Average yield, all fields: 124.

The growing conditions in 1952 were ideal. This is shown by an average yield in the "100 Bushel Corn Adventure" of 124 bushels per acre. The state average corn yield for 1952 was 58 bushels, which was about 14 bushels higher than the ten-year average. The above data show the higher yields are associated directly with the higher plant populations.

The interest in fertilizer prescriptions increased. In 1953 about 1,500 were written for corn fields in thirty-seven counties in Wisconsin. Farmers were not the only ones interested in this program. The Extension Service through the county agents enlisted the help of fertilizer and seed dealers. Through their combined efforts 756 fields were harvested, the average yield on these fields being 102 bushels per acre as shown in Table 20.

TABLE 20

YIELDS OF CORN IN 1953 FERTILIZED IN ACCORDANCE WITH PRESCRIPTION FOR 100-BUSHEL YIELD, ARRANGED ACCORDING TO YIELDS AND POPULATIONS

Yield Ranges (bushels per acre)	*Number of Fields in Each Range*	*Average Yield for Each Range* (bushels per acre)	*Average Corn Population* (stalks per acre)
Under 100	332	85.8	13,900
100 to 110	166	105.1	14,960
110 to 120	128	114.6	15,260
120 to 130	73	124.5	15,880
130 to 140	41	134.0	16,640
140 to 150	12	146.2	17,050
Over 150	8	159.8	17,850

Total number of fields 765 Average yield, all fields 102.2

Counties in the northern as well as the southern part of the state were included in 1953. As a result, yields were down slightly but still over 100 bushels per acre. The northern part of the state has a shorter growing season, so corn yields are lower than in the southern part of the state.

Of the farmers getting less than 100 bushels per acre, the great majority did not comply entirely with the fertilizer prescription. The top yielding field, on the William E. Rank and Son farm, gave a yield of 169 bushels per acre. The yield was obtained not only because of the fertilizer prescription, but because of the careful planning methods and good cultural practices used by the Ranks. Their stand of corn was nearly perfect—about 19,000 plants per acre.

Mr. Rank calculated the cost for several of his fields. On this

high producing field, the total costs including land rental were $95.44 an acre. The fertilizer charge was about $28 an acre. The cost of the corn was $0.56 a bushel, picked and hauled to the farm.

In another field on this farm, using fertilizer costing $18 an acre but with smaller populations, the yield was 117 bushels per acre. This corn cost $0.88 a bushel. Although the Ranks did not grow any corn without fertilizer, it is estimated that their yield without fertilizer would be about 70 bushels per acre and that this corn would have cost over $1.00 a bushel to produce.

In addition to fertilizer recommendations, directions are given as to proper placement of fertilizer, weed control, and planting populations. It is necessary to plant from 10 to 20 per cent more kernels than the desired fall population. Farmers are enthusiastic about this type of recommendation. Although the prescriptions may call for ten times as much fertilizer as many farmers are accustomed to use, they do not complain. They can easily figure out that following a specific plant food prescription gives maximum profits per acre.

INTERPLANTING DOES NOT NECESSARILY REDUCE AMOUNT OF MOISTURE AVAILABLE TO CORN

Interplanting of grasses or grasses and legumes is a part of this new method of growing row crops. But this does not necessarily mean these interplanted crops compete with corn for the moisture available. In fact, their presence may actually make more water available to the corn crop.

Surface mulching and sod cover have been shown to greatly increase the absorption of water by the soil. The Soil Conservation Service showed that out of a total of 9.375 inches of water applied at a uniform rate over a five-hour period, 5.38 inches were absorbed by Muscatine silt loam in bluegrass pasture. Only 1 34 inches were absorbed by a similar soil just across the fence in corn. The bluegrass sod was instrumental in getting 4.04 inches more of the 9.375 inches of water into the soil.

In addition to the low intake of bare soil the loss of moisture by evaporation from the soil surface is relatively high. On small fallowed areas of Abilene clay loam, over 60 per cent of the rain that fell during a two-year period at Spur, Texas, was lost by evaporation. Similar, and even greater, losses by evaporation from the soil surface have been reported on the High Plains. During the hot summer, the surface six inches of clay soils may lose one-half inch of

water by evaporation within a few days after a rain. The moisture stored below a depth of six inches, however, is relatively stable, and losses due to evaporation are negligible.

TABLE 21

TOTAL AMOUNT OF INFILTRATION DURING FIVE-HOUR PERIOD

Soil	*Bluegrass Pasture* (inches)	*Cornland* (inches)	*Difference due to Land Use* (inches)
Muscatine silt loam	5.38	1.34	4.04
Tama	5.03	1.51	3.52
Berwick	3.48	1.21	2.27
Clinton	2.77	2.17	0.60
Viola	1.63	1.28	0.35

These losses may be reduced by increasing the depth of moisture penetration. On sandy soils, water penetrates deeper than on clay loam soils, so the losses will be less on sandy soils. Surface mulches or sod crops increase infiltration, aiding deeper penetration of water so that there will be a greater amount of water available for plant growth.

WELL FERTILIZED CORN USES WATER MORE EFFICIENTLY

It has been shown that plant cover increases the amount of rainwater that enters the ground. The efficiency of this water can be increased by the use of fertilizer.

In addition to sharply increasing corn yields, liberal use of fertilizer materially reduced the amount of water required to produce a bushel of corn in Central Missouri.

Corn was grown on well fertilized soil in a four-year rotation of corn, wheat, and two years of meadow, with grain and hay crops removed. It produced 79 bushels per acre. This corn required sixteen inches of soil moisture, because more than 5,600 gallons of water were required to produce a bushel of corn.

Corn also was grown on unfertilized soil in a corn-oats rotation with only the grain removed. It produced eighteen bushels per acre. About fourteen inches of water were needed; on a per bushel basis, some 21,000 gallons of water were required.

Soil retains water that neither drains away nor rises to the surface by capillarity to be lost by evaporation. However, this water in the soil may be extracted by plant roots when they grow into it. Me-

dium-textured, gravel-free soils retain about one inch of water in each six-inch layer of soil. Light-textured, gravelly soils contain about two-thirds of an inch of water in each six-inch layer.

ROOTS UTILIZE STORED WATER

The amount of water plant roots may remove depends upon depth of root system and the amount of water in each layer of soil. Some soils are underlain by rock and cemented hardpans into which roots do not penetrate They store only three inches of water for corn use between rains.

The Putnam and Marshall soils of north Missouri and the bottom soils throughout the state are deep, containing as much as eight to ten inches of water in four to five feet of soil Corn, well fertilized, can use this because it will grow roots to reach these depths

One year, leaves of unfertilized corn growing on Sanborn Field at Columbia curled, despite ample moisture in the soil below three feet Adjacent plots of fertilized corn showed no injury Corn on these plots exhausted soil moisture to a depth of 42 inches Roots of fertilized corn penetrated the soil for four feet in a subsequent year. In some instances, corn removed over nine inches of water from Putnam soil.

Corn used up over one inch of water per week during the summer. If there were less than three inches of water available, corn would be a complete failure on the shallow soils However, the yield would be only slightly lowered on the deeper soils

DIFFERENCES IN ROOT DEVELOPMENT

Measurements were made of the use of soil moisture from the upper three and one-half feet of soil Root development under fertilized crops was greater than for unfertilized They penetrated deeper into the soil, too. Thus, corn growing on heavily fertilized plots had root development sufficient to take water at a greater rate Since roots penetrated to greater depths, the plants had a greater water supply than shallow rooted corn on unfertilized soil. By early August, plant roots in the fertilized area had penetrated below the three-and-one-half foot depth. So these plants actually took a little more water from the soil than could be measured in this experiment.

Water removed from the unfertilized plot was about one-eighth inch daily throughout the season, which was also the approximate

rate water was removed from heavily fertilized plots for the first one-third of the season. After that time, the removal was more than one-fourth inch daily. Evaporation of moisture from the soil was an important factor during the early growth stages. As corn grew, the crop required more water, but shading of the soil cut evaporation losses.

SIX YEAR AVERAGE YIELDS

The yield differences in 1953 were quite similar to those of previous years. During the past six years, average yields in the corn-wheat-two-years' meadow rotation were 100 bushels of corn, 23 bushels of wheat, and a little more than two tons of hay per acre.

In the two-year rotation of corn and oats without fertilizer, average yields were 23 bushels of corn, and 6 bushels of oats per acre. However, with a similar two-year rotation of corn and oats, on heavily fertilized soil and sweet clover for green manure, yields averaged 98 bushels of corn and 37 bushels of oats.

Not only did yields per acre increase, but shelling percentage of the grain likewise increased. Corn grown on heavily fertilized soil shelled 79 per cent, unfertilized corn shelled only 70 per cent.*

Soils heavily fertilized received 5 tons of lime, 1,000 pounds of rock phosphate, and 100 pounds of muriate of potash, which were added at the beginning of the study. Each year the land was in corn, 300 pounds of 3-13-12 and 100 pounds of nitrogen were used per acre. The two-year fertilized area was treated in a similar manner except only 66 pounds of nitrogen were used per acre. Additional potash and phosphate were required after the first round of the rotation, the four-year rotation required more of these elements than did the two year rotation.

EXERCISE

1. Have soil tests made of different fields of your farm. Now determine the quantities of N, P_2O_5, and K_2O needed on each field to produce a hundred-bushel corn crop.

QUESTIONS

1. What is happening to our method of growing corn? How does this differ from our customary method? What are the main objectives of the new method?

2. How is the new method of growing corn affecting our use of fertilizer? How does this affect erosion?
3. How does this new method affect soil aggregation? Infiltration? The amount of water available for crops?
4. How is cheap nitrogen affecting our farming practices? What is it doing to use of legumes in crop rotations?
5. This new method of growing crops makes it unnecessary to use crop rotations. That is, corn can be grown year after year on the same land. Amazing as it seems, we can increase corn yields at the same time. Explain how this is possible.
6. This method of farming makes it possible for the first time to build up the organic matter content of our soils. How does it accomplish this?
7. Why are soil tests so important to the success of this system?
8. What is meant by "fertilize by prescription"? What are the advantages of the method?
9. How does the use of large amounts of plant food affect the use of water by plants? What is the importance of this in dry years?

16

Wheat Production with Trashy Farming

WHEAT production with trashy or stubble-mulch farming is a comparatively new method of growing wheat. The method, which was first developed and utilized on a large scale in connection with the production of wheat in the Great Plains, uses crop residues on the surface of the ground.

During recent years, this system of preparing land for seeding has spread over millions of acres of wheat land. Commonly called stubble-mulch farming, it consists of leaving the residue from past crops on the surface of the ground. Land is prepared and the wheat is planted so as to leave the stubble on the ground as mulch.

The residue may consist of the stubble or the stubble and combined straw left on the land. Weed growth also serves as residue. Care should be taken that the weeds do not deplete the soil moisture needed for the new crop. Weeds should be killed before they produce seed.

WIND EROSION CONTROL

Straw and stubble maintained on the surface in sufficient quantity is the simplest and surest way to prevent wind erosion on wheat land. To be most effective, the straw should be anchored in the soil. As the straw gets older and run over by tractors and machinery, it tends to get brittle and broken into short pieces. If it does not be-

come too short it can be partially buried at the end of the season with some straw still sticking out of the ground. This will hold other loose pieces of straw. Soil movement by wind may be stopped.

WATER EROSION CONTROL

Water erosion, as well as wind erosion, is prevented so long as there is good residue cover on the land. Stubble from July harvested wheat is left undisturbed until the following May. This protects the soil from water and wind erosion for a ten-month period. The land should be fallowed in such a way that residue is left on top of the ground until the next crop is established. It should stay on top of the ground through the following winter and early spring months, so that protection will be provided for another eleven months. By this time, the combination of residue and growing wheat should protect soil until harvest time in July.

This protects the soil from both water and wind erosion for two years. At the end of this period, the wheat-fallow rotation is repeated. It is possible to protect land against water or wind erosion continuously if this stubble-mulch system is followed. It is particularly well adapted to an alternate wheat-fallow method.

CONSERVATION OF MOISTURE

If properly managed, stubble mulch may increase the moisture content of the soil over plowing and may improve soil moisture conditions a number of ways. Standing stubble catches snow over winter. Mulch enables the soil to absorb more water during rains and reduces evaporation. There is less drying out between rains, which permits water from the next rain to penetrate deeper into the soil. Very little of it will be used to wet a dried soil layer at the surface. In summer, it intercepts the falling raindrops and prevents or reduces damages from splash erosion. The infiltration rate is kept high and runoff losses low during heavy rains. If the soil is already filled with moisture to some depth, additional water saved by the mulch pushes the moisture down deeper than the smaller intake on plowed land. Water in the second, third, or fourth foot at seeding time does much to insure a good yield of wheat.

The Soil Conservation Service conducted studies at Amarillo, Texas, over a period of seven years. The aim was to determine the effect of different tillage methods on the moisture content of the

soil. Soil moisture on continuous wheat plots was not consistently higher under subtillage than under the other cultural methods. In some cases, it was even lower.

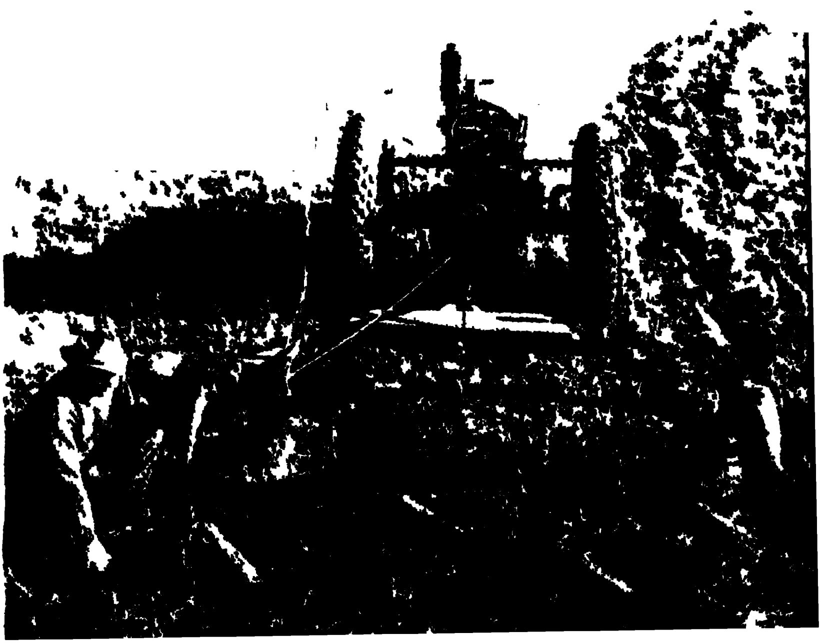
TABLE 22

AVERAGE MOISTURE CONTENT TO A DEPTH OF THREE FEET OF STUBBLE MULCH PLOTS OCTOBER 1948 AND MARCH 1949

Tillage Method	*Land in*	*Moisture Content* Oct. 1948 (per cent)	*Moisture Content* Mar. 1949 (per cent)
	Continuous wheat		
Moldboard plow	Wheat	16.0	18.1
One-way	Wheat	16.3	17.2
Subtillage	Wheat	15.1	20.1
	Wheat-fallow-wheat system		
One-way	Fallow	16.2	19.0
Subtillage	Fallow	15.[illegible]	20.1
One-way	Wheat	18.1	17.3
Subtillage	Wheat	21.5	18.9

The low moisture on the subtilled plots may have been due to higher yields of grain on these plots. More moisture may have been

Figure 16.1. One type of subsurface tiller used at Amarillo, Texas. The sweeps are set flat to cut three inches beneath the surface. (Soil Conservation Service Photo)



used by the higher yielding crop on the stubble plots, and even though there was less moisture in the soil at the end of the season on these plots, more moisture may have been used by the crop.

The idea is partly supported by the fact that land in fallow for a year had more moisture when subtilled than when cultivated with a one-way disk. This shows the efficiency of the stubble mulch system in storing moisture.

Of especial interest in this connection are the data comparing moisture reserves in the stubble mulch plots in late March, 1949, about five and a half months after the October sampling. Subtilled fallow and continuous wheat plots were able to retain sufficient winter precipitation to more than overcome the moisture deficiencies of the previous fall. At this season of the year, they exceeded the one-way and moldboard plow plots in moisture content.

SUBTILLED MULCH MAKES BIGGEST YIELDS

As practiced in the stubble mulch system of farming at Amarillo, Texas, subtillage produced greater yields of wheat than moldboard or one-way plowing. A comparison was made of the effects of moldboard plowing, one-way plowing, and subtillage on yields of wheat. This comparison was made on the continuous wheat plots at Amarillo during the period of 1942 to 1948, inclusive. The average of the results are shown in Table 23.

TABLE 23

AVERAGE ANNUAL WHEAT YIELDS PER ACRE FROM STUBBLE MULCH PLOTS IN CONTINUOUS WHEAT, 1942–48

Tillage	*Yields* (bushels)
Moldboard plow	12.5
One-way plow	13.2
Subtillage	15.1

Continuous subtilled-wheat plots produced an average of 2.6 bushels more wheat per acre than the moldboard plow plots. They also produced 1.9 bushels more than where the one-way was used. Increased yields during the period these tests were in operation attest to the effectiveness of stubble mulch in controlling erosion. It is also interesting to note that the average annual yield on the subtilled plots was 15.1 bushels per acre.

The grain yields for the seven-year period are shown in Table 24

where two implements, the one-way plow and the subtiller, were used on plots planted to wheat one year and fallowed the next.

TABLE 24

AVERAGE ANNUAL WHEAT YIELDS OF WHEAT-FALLOW-WHEAT SYSTEM, 1943-48

Tillage	*Yields* (bushels)
One-way	18.8
Subtillage	21.6

Subsurface tillage increased wheat 2.8 bushels per acre over cultivating with a one-way disk in a wheat-fallow system. Wheat after a year of fallow (uncropped) consistently out-yielded wheat planted year after year. This effect was pronounced in dry years. Here, the moisture stored during a fallow year meant the difference between crop success and failure. In addition, fallowing made the production and maintenance of a stubble mulch possible. This protects the soil from blowing in dry years or wet.

STUBBLE MULCH IN A WHEAT-FALLOW SYSTEM

The stubble-mulch system is well adapted in regions where alternate wheat-fallow is a common practice, because wheat yields are usually high after a year of fallow.

Where fallow follows a heavy straw crop, there will be little difficulty and about fourteen months to prepare the seedbed. This allows some of the straw to decay. Machinery passing over it breaks it up, and, too, some of the straw is buried in the process of tillage.

Seeding wheat with suitable implements leaves practically all the residue on the surface to provide wind- and water-erosion control and soil improvement.

Plant material produces more desirable effects when left on the surface than when turned under. From one to one and a half tons per acre at seeding time is needed to protect the soil from wind erosion and raindrop splash.

During years of high wheat yields, the straw should be cut in lengths short enough not to interfere with planting operations. All tillage operations and the drilling of grain must be done so as to leave the straw on the surface at seeding time.

As farm machinery becomes better suited, larger and larger amounts of straw can be left on the surface of the ground at all

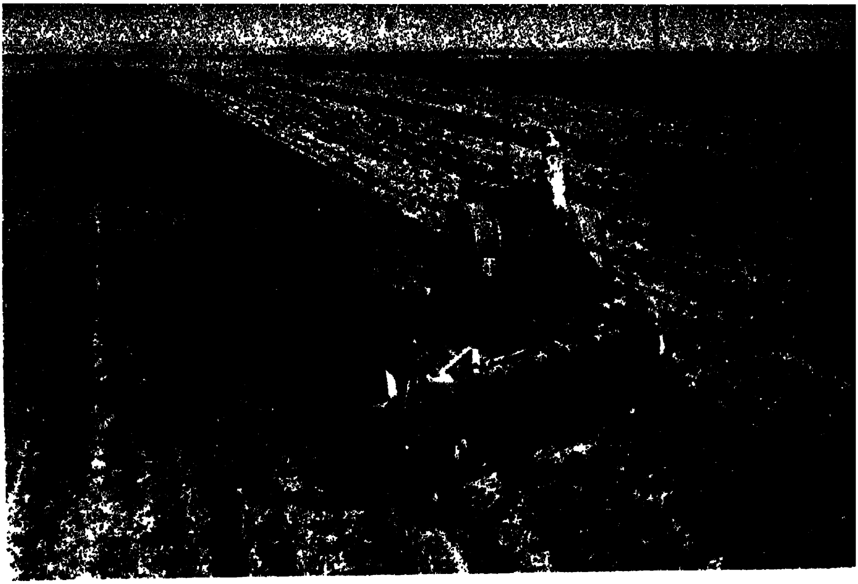


Figure 16-2. One-way disk being used on wheat stubble in Oregon. The machine should be set to run shallow and leave all the straw possible on the surface. (Soil Conservation Service Photo)

times. Straw mixed with the surface soil is not effective in controlling erosion, neither is it as effective in improving the soil as when left on the surface. Straw left on the surface protects and improves the soil better. It decays slowly and is effective over a longer period of time.

SUBSURFACE TILLAGE ON FALLOW LAND

Subsurface tillage is accomplished by cultivating beneath the surface. When stubble and other crop residues are present, they are left on the surface to form a stubble mulch. When this type of tillage is used on fallow land, it is referred to as stubble mulch fallow.

A stubble mulch on the surface of fallow land aids in controlling wind and water erosion—wind erosion, by reducing surface wind velocity; water erosion, by reducing raindrop splash and runoff. Wheat yields about the same on stubble mulch fallow as on fallow cultivated by other methods. There appears to be little difference in yield of spring wheat on fallow. This is true, regardless of the tillage method used, provided operations are timely and erosion is controlled.

All methods of fallow in general use have advantages and disad-

vantages. Two main problems are encountered in a stubble mulch system of fallow: One is in connection with the tillage operations, and the other is in seeding the crop. It is difficult to cultivate through large amounts of straw, although more difficult to control certain weeds with a subsurface tiller. Large amounts of trash make wheat planting more difficult with some drills.

Farmers usually experience some difficulty when they try stubble-mulch tillage. Because of this they should start with a small acreage that will enable them to become familiar with operation of stubble mulch equipment. They will learn the limitations of the system before trying it on a large acreage. If an operator starts out with too large an acreage, he may get discouraged and revert to some other tillage method.

Little of present farm equipment handles stubble satisfactorily, because most of it was designed to deal with trash under and not above ground. Equipment designed to handle stubble mulch does so with ease. If a farmer has proper equipment he will have little difficulty.

All trash should be left on the surface to protect the soil from wind and water. This is the only way to keep improving the soil.

Figure 16-3. Straw cutter used in Oregon for reducing tall stubble into shorter lengths. The cutting principle is the same as that used in rotary lawnmowers. (Soil Conservation Service Photo)

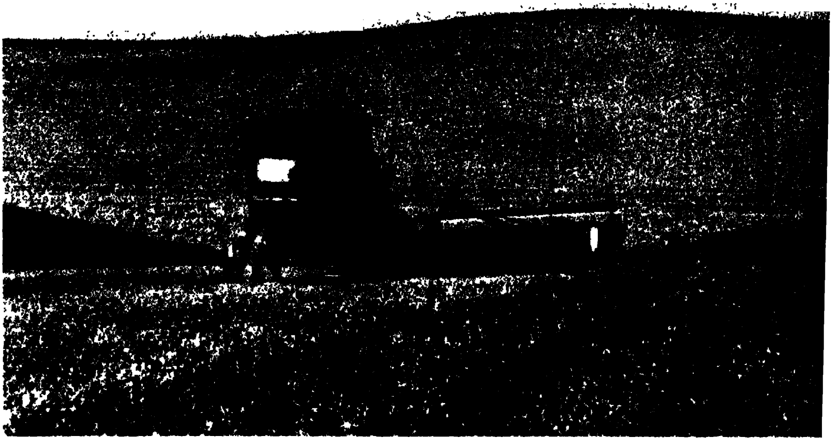


Figure 16-4. Combine equipped with a straw spreader operating on typically rolling grainland in Solano County, California. When spread uniformly over the ground surface, the straw causes less difficulty during later operations. (Soil Conservation Service Photo)

If there is too much straw to work through, it should be shredded—chopped into short enough lengths so it can be worked through.

Short straw can be cultivated and planted through more easily than long straw. In the absence of a suitable machine to cut the straw into short lengths, a disk-type implement may be used for one or more of the tillage operations. Each disking covers some straw, however, and the number of diskings will depend on the amount of residue the farmer can handle with his equipment. The disk used may be any one of several types on the market, but the important thing is the depth of operation.

Disking should be shallow if it is to be followed with some type of subsurface tiller. Subsurface tillers operate more satisfactorily when working below the depth of disking, and are more effective in killing weeds if operated to a shallow depth. If a subsurface tiller is worked at a shallower depth than the land was disked, the stubble will catch on the sweeps or blades. The machine tends to push soil ahead of it, so often becomes clogged. Disking should not be over three inches in depth. Subsurface tillage done much deeper than that is not effective in killing weeds.

USE OF STRAW SPREADERS

If the crop is harvested with a combine, a straw spreader should be used to prevent an excessive accumulation of straw in windrows Heavy windrows of straw cause difficulty during fallow operations and at seeding time

TYPES OF SUBSURFACE TILLERS

There are several types of subsurface tillers on the market—the straight blade, wide sweep, narrow sweep, and rotary rod weeder In selecting a subsurface tiller, it is important to consider such things as size, clearance, weed killing ability, and sturdiness of construction

If a machine is too wide, difficulty will be encountered on irregular ground If a wide piece of machinery is needed, it is advisable to have it in sections to make it flexible Wide machines built in sections follow ground contours better than machines of similar width built on rigid frames A wide, rigid subsurface tiller does not have uniformity in depth of cultivation In turning, they cause variation in draft and are poor at killing weeds

It is important to select a subsurface tiller that has *sufficient clearance* to go through large amounts of stubble Stubble in which large Russian thistles are present is especially difficult to get through Unless the machine has a lot of clearance, it will not operate without clogging

Subsurface tillers vary in their weed killing ability Those that stir the surface soil are more effective and they kill shallow rooted weeds better than machines using shearing action alone Because shallow rooted weeds are the most difficult to control with subsurface tillers, special consideration should be given this problem when selecting a machine

Sturdiness of construction is also important in a subsurface tiller If the machine is not well built, breakage and bending results With the large sweeps generally present on subsurface tillers, it is especially important that these sweeps be kept running as true as possible It is difficult to get a subsurface tiller to operate satisfactorily if the sweeps or beams are bent

Often the rod weeder is not thought of as a subsurface tiller Actually, it fits into a stubble mulch system very well in some localities The rod weeder usually operates best when some other subsurface

tiller is used for the first operation. In light soils free from rocks, the rod weeder with shovel attachments can be used for the first and succeeding operations where crop residues are not too heavy.

OPERATION OF SUBSURFACE TILLERS

In order to get good weed kills with subsurface tillers, a *uniform shallow cultivation* is necessary. A uniform depth can best be maintained if the machine is weighted enough to hold it in the ground at all times. The weight of the machine holds the sweeps in the ground, and the wheels keep the sweeps from going too deep. Failure to properly weight subsurface tillers may also result in the sweeps or blades coming out of the ground. If the sweeps come out of the ground, the machine generally clogs. The variation in depth of cultivation resulting from lack of weight also causes a draft problem. With insufficient weight a machine set to penetrate the hard spots goes deeper in soft areas. This usually greatly increases the load.

Better weed kills and more satisfactory operation is obtained, if a subsurface tiller is pulled at a *fair rate of speed*. The slower the rate of speed the less soil stirring results and greater is the tendency to clog. About five miles per hour is a desirable speed.

Subsurface tillage done on *warm, dry days* results in better weed kills than when the weather is cool and damp. Subsurface cultivators also operate better if the *soil is not too wet*. Subsurface tillers should be operated under favorable conditions whenever possible to increase their efficiency as weed killers.

USE OF TREADERS

Under some conditions, a treader may be used to advantage following a subsurface tiller. A satisfactory treader can be made by reversing the prongs on a certain type of rotary hoe. If the proper type of treader is used, it will help break up the straw into shorter lengths and will also anchor the straw in the soil so it won't be blown away as easily. The treader also helps in controlling weeds, by breaking up clods in which weeds might otherwise continue to grow. It rolls larger weeds over and pulls them up. The use of the treader generally results in a more easily seeded seedbed. A treader should not be used when the stubble is light, because it pulverizes. This creates conditions that favor soil drifting.

REQUIREMENT FOR STUBBLE-MULCH FARMING

Equipment should be carefully chosen and properly used to prepare seedbeds under a stubble-mulch system. A good seedbed for wheat is one that is in good tilth, is weed-free, and has enough residue on the surface to protect the soil and the young crop from either wind or water erosion.

There is no set of tools best for all conditions. There are many combinations of tillers, packers, weeders, and drills that may be so used as to result in a good job. Whatever equipment is used the proper job must be kept in mind at all times.

QUESTIONS

1. What do we mean by stubble-mulch farming?
2. How does stubble-mulch farming differ from the regular method of farming?
3. What are the main advantages of stubble-mulch farming?
4. How does stubble-mulch farming control erosion?
5. Where is stubble-mulch farming practiced?
6. What is the chief drawback to stubble-mulch farming?

17

Grassland Farming

TODAY agriculture in the United States is undergoing greater change than at any time since the settlement of this country two hundred years ago. In the past, we have been cash- and row-crop farmers. We have emphasized corn, the cereal grains, cotton, and tobacco. We have cleared the forests, plowed the prairies of the Midwest, and turned the bunch grasses of the Northwest. While producing more grain, more fiber, and more of the other cash crops, we built the greatest nation on earth.

Once there was land enough for all. There was an enormous storehouse of productivity in the soil. This was built and held there for uncounted centuries by continuous grass cover. Once there was plenty of feed for our grazing herds on the rough, poor land unsuited for production. Besides, everyone knew that it was the grain we fed our cattle that produced the milk and the beef. Pastures and hay crops were thought of as "roughage." They were poor crops, indeed; in fact, they were not crops at all. Certainly, they did not deserve or get a place on productive cropland. Neither did they warrant nor receive fertilization or other care.

But all of this is changing. We are now witnessing a conversion of our agriculture from a cash- and row-crop system to a grasslands system. It is a great movement—almost a crusade. It is a movement that has been progressing gradually throughout the United States, although it has progressed more rapidly in some areas than in others.

We are heading toward a grassland agriculture for several reasons. First, our grasslands have an enormous productive capacity, if they

are properly treated. There are almost a billion acres of permanent grasslands in the United States, and most of them are unimproved. Suitable liming, fertilizing, reseeding and management practices would more than double yields on hundreds of millions of acres of permanent grasslands. These practices would assure optimum production.

For example, pasture renovation in the Northwest has resulted in increases in forage production of four to six times that on unimproved pastures. In Georgia, a well-fertilized Coastal Bermuda grass pasture produced in one season 569 pounds of beef and produced 2,500 pounds of high quality hay per acre in addition. At Beaumont, Texas, proper fertilization and seeding of adapted grasses and legumes in rice stubble pastures increased beef production 300 per cent. Similar improvement could be cited from work in Missouri and elsewhere.

CHEAPER FEED UNITS

Second, it has been shown experimentally that improved grasses can produce as many food units per acre as corn or the other feed grains. This applies to much of our cropland. Grasses produce feed at lower cost per unit and with greater returns per unit man-hour of labor than cultivated land.

Third, improved grasslands can produce, as pasture, hay, and silage, most or all of the feed required for livestock. Dairy cows can produce 80 per cent as much milk on improved pasture alone as on the best combinations of concentrated feeds. They have produced 8,000 pounds of milk per year without any grain or other concentrates.

Fourth, large portions of our population are milk-and-meat hungry. It has been estimated that 40 per cent of our families have diets that are deficient in calcium and 50 per cent have diets that are deficient in protein. The best way to insure sufficient minerals and protein in the human diet is through such animal products as milk, meat, and eggs. But if our experience of World War II is repeated, these dietary deficiencies will increase. It was meat, butter, fats, and other livestock products that became critically short during the war.

If we are to avoid recurrence of those shortages and dietary deficiencies, we must have more livestock products and at prices that place them within reach of the greatest number of our people.

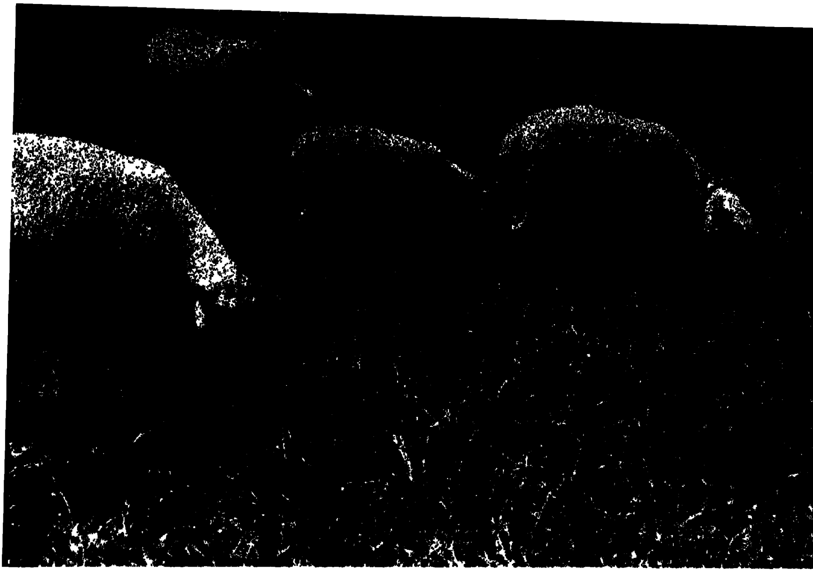


Figure 17-1. Mixture of ladino clover, tall fescue, and lespedeza in Warren County, Kentucky. Ten acres carried 120 sheep during fall grazing season. (Soil Conservation Service Photo)

By a grasslands program, we can have increased supplies of livestock products. These can be produced at lower cost and will not interfere with production of other food and fiber crops. Neither will they compete for short supplies of feed grains. But without a grasslands program, we must content ourselves with less total food. Our diets will be made up of lower amounts of meat, milk, butter, and cheese.

Fifth, wool is already a critically short commodity in this country. Sheep can, and at present do, exceed other classes of livestock in the proportion of nutrients they obtain from forage. Improved grasslands are required to feed sheep to produce the wool that is so seriously needed.

Last, improved grasslands are required in our cropping systems. Grasses provide sustained maximum production of other cultivated crops. Until recently, no cropping schemes had been devised that would maintain soil organic matter. Schemes based on adequate proportions of grasses and legumes in rotation do so. The so-called cultivated crops permit serious soil losses by erosion. The processes of annual plowing and periodic tillage is in itself a soil-destroying process. As soil fertility and organic matter decline, soil structure is

lost. As soil structure is lost, tillage difficulties increase, crop yields decline, and erosion increases.

Grassland farming is a system. It is based on adequate and intelligent use of grasses and legumes. It is a system in which grasslands are an integral part of the cropping scheme. Some areas, unsuited for cultivation, are converted to permanent grasslands by this system. Other areas are placed in crop rotations. In this case, the system has a sufficient proportion of grasslands to protect the soil. It also gives profitable and sustained production of the cultivated crops. In fact, in grassland farming, pasture, hay, and grass silage are cultivated crops. They receive and warrant as much care as is given other cultivated crops.

SOIL FERTILITY AND PASTURES

The October 1950 issue of *Successful Farming* had an excellent story about Ben Moy. Ben Moy is a Buffalo County, Wisconsin, farmer. He threw away his plow and sowed his hilly, eroded, 240-acre farm down to bromegrass and alfalfa. His present equipment is limited to that required to lime, fertilize, seed, grow, and harvest grass-legume forage.

A great many other intelligent dairy farmers on hilly land have come to realize that plowing and cultivating are enemies of the soil. They have found that corn on a dairy farm is parasitic on the grass-legume forage crops. These are needed in much greater quantity and in much higher quality for economical milk production.

The use of limestone and superphosphate has been recommended for many years. They have been used to increase the productivity of permanent bluegrass pastures Where topography of the land permitted, disking and reseeding with grasses and clovers were recommended. The effects of such practices were often phenomenal.

In Europe, carefully saved manure and basic slag[1] have long been used with excellent effects on permanent pastures. The manure serves primarily as a source of nitrogen and potassium. The basic slag supplies lime and phosphorus. Both materials are important sources also of the minor elements that are missing from large areas of pasture land.

It was not until the end of the first World War that really in-

[1] Basic slag is a by-product of smeltering plants.

tensive systems of pasture management came into being. This was made possible when the products of the tremendous nitrogen-fixing factories of Germany and England were diverted from explosives to agriculture.

One such system was started at Hoenheim, Germany, in 1917. This system made heavy use of nitrogen fertilizers and rotational grazing. Supported by the Stickstoff Syndikat in Berlin and by Imperial Chemical Industries in London, the system began to receive serious consideration in this country about twenty-five years ago. The first experimental project of this type in the United States was put into operation at the Dairy Research Farm at Sussex, New Jersey, in 1927. It has been in operation ever since.

PROGRAM BROUGHT RESULTS

Notwithstanding the known value of lime, complete fertilizers, improved strains of grasses and legumes, and rotational grazing, progress in pasture improvement and management had been dishearteningly slow. But the "Green Pasture" program advanced by the Northeastern States, and similar programs in other sections of the country, resulted in alerting large numbers of farmers. They became aware of the possibilities for profit in improved grasslands.

In New Jersey, stress is laid on having good grazing from early April to late November. This is a period of more than 300 days. The program includes the use of winter grains for early spring and late fall pasture. A part of it is rotational grazing of bluegrass–white clover sods. The growing of orchardgrass-ladino clover, sudangrass–soybean, and bromegrass- alfalfa mixtures for in-between grazing and hay purposes is important. Various other forage plants, such as Reed's canary grass, sweetclover, and birdsfoot trefoil are also used.

BLUEGRASS

There has been considerable discussion recently of bluegrass as a weed. Some have suggested replacing it with improved grasses and clovers on dairy farms. But bluegrass is seldom given an opportunity to demonstrate its real value. It is usually grazed continuously from early spring to late fall. Furthermore, the native white clover, which grows here and there and comes and goes from one year to the next,

is expected to supply the grass with all the nitrogen that it requires.

The falseness of the belief that clover will supply enough nitrogen for bluegrass is apparent following an application of a nitrogen fertilizer. If one wants really good bluegrass pastures, they should be given the equivalent of 500 pounds of 10-10-10 fertilizer an acre every year. This starts the grass early in the spring. It extends grazing well into the summer. The grass comes on again with luxuriant growth in the fall.

A second application of 50 pounds of nitrogen after the first grazing will aid. It will extend the grazing further into the summer. It will also bring it back earlier in the fall. The protein and mineral content of such pastures are about all that can be desired.

If bluegrass-white clover fertilized pastures are grazed as they should be, clover stands can be maintained at as high level as they would have been had no nitrogen been applied. Proper grazing means close grazing followed by a resting period and clipping with a mower.

If available, a five-ton-an-acre application of manure, supplemented by 50 pounds each of phosphoric acid and potash, will accomplish the same purpose. It will also increase the stand of clover. After such manuring at the New Jersey Dairy Research Farm, the white clover coverage was 25, 44, 41, and 54 per cent for four successive years.

There is abundant evidence that poor bluegrass pasture can be greatly improved. This requires the use of some of the more modern implements. Implements that stir up the old sod without turning it upside down are best. The efficiency of such machinery has been greatly increased. Poor hillside pastures of any type can be very quickly improved by this process. If pastures are limed properly, fertilized with 500 pounds of 10-10-10, and reseeded to grass-legume mixtures, improvements result. Nitrogen is usually needed to overcome the competition of the soil microorganisms working in the old sod.

Orchardgrass-ladino clover lowland pastures in New Jersey produced 5,500 pounds of dry matter an acre. This resulted from regular use of lime and the annual application of 250 pounds of 0-20-20. Better results would have been obtained by doubling the potash. Doubling the potash is recommended.

Yields can be stepped up still higher. This is done by the application of larger amounts of fertilizer or by the supplemental use of

manure. The possible dry matter production in grass-alfalfa mixtures at New Brunswick was found to be nearly 10,000 pounds of dry matter an acre annually. This was obtained over a two-year period following seeding. This was on well-limed soil which received the equivalent of 1,000 pounds of 0-12-12 fertilizer and 25 pounds of borax an acre annually.

Quality of product tends to deteriorate with increasingly high yields above a reasonable level. This is due in part to a higher proportion of stems to leaves. Quality also tends to be lowered from one year to the next. The soil's capacity to deliver enough of both major and minor mineral elements to the forage plants dwindles. The amounts delivered do not meet the needs of the animals that consume the forage. As the acidity of the soil increases, the availability of all the minor elements, except molybdenum, tends to increase. Acidity begins to increase the first year after seeding. The manganese content of alfalfa was higher each year over a three-year period. But the cobalt content fell successively. Zinc content fell by the second year.

MANAGEMENT IMPROVES IRRIGATED PASTURES

Properly prepared and managed irrigated pastures produce two to three times as much beef as unimproved ones. An unimproved irrigated bluegrass pasture produced an annual average of 200 to 250 pounds of beef per acre over a four-year period. It was operated by the Kittitas Soil Conservation District in Washington.

At the same time, a 41-acre pasture, similar to the unimproved one, produced an average annual acre yield of 549 pounds of beef. It was seeded to an appropriate grass-legume mixture and fertilized annually with about 300 pounds per acre of 18 per cent superphosphate.

The average cost per pound for producing the beef on improved pasture during this four-year period was 7.3 cents. This figure includes the cost for the first pasture season The plants were not fully developed the first year. The average net income per acre was $90.84 annually for four years.

Supplementary irrigation of a well-fertilized Bermuda–ladino clover pasture in Georgia increased the production of dry forage 27 per cent, and protein 67 per cent. The increased forage and, particularly, the increased protein, was due largely to a greater survival and growth of ladino clover with irrigation.

In any irrigation program all other limiting factors in plant growth should first be corrected. Before purchasing expensive permanent equipment, the farmer should be sure his type of operation gives sufficient returns. It should do this over a period of years to justify the cost of applying supplemental water. In some cases, it may be more profitable to alter cropping systems or farm enterprises than add irrigation management to the farm plan.

THE POTASSIUM PROBLEM

Special attention is called to the potassium problem. The soils of most permanent pastures have been robbed of this element over the years. When it is finally added, a large part of that applied is often fixed by the soil. This fixed potassium is only slowly available to plants. Under these conditions, in order to get the effect desired, very heavy applications may be required. Such applications need to be continued until the potassium level of the soil has been raised materially.

Orchard grass was found to contain one per cent more potassium than the legumes associated with it. Similar findings have been reported with bluegrass and bromegrass. Crabgrass, dandelions, shepherd's purse, and dock have very high potassium-accumulating powers. These plants often contain from two to three times as much potassium as the alfalfa growing with them. Competition for potassium by grass and weeds is one of the important causes of disappearance of white clover in bluegrass pastures. Similar troubles are experienced in grass-legume hay mixtures.

TIME OF APPLICATION

It is generally assumed that fertilizers can be applied to pastures with equally good effect at any convenient season of the year. It is too bad this is untrue. We need to distribute farm and factory labor over a longer part of the year. And it is much easier to get over the land in summer and fall than in early spring. But in a five-year test of nitrate of soda and sulfate of ammonia on permanent pastures at New Brunswick, the yields were 36 per cent greater on the average from March applications than from those of October. In similar comparisons of a phosphate-potash mixture, the yields were 22 per cent higher from the March applications.

When soil microorganisms reawaken each spring, there is need for extra nitrogen and phosphorus. These elements are found in very high percentages in cells of microorganisms. Some bacteria have been found to contain over 10 per cent nitrogen and 2 per cent phosphorus. Such microorganisms offer serious competition with grass and clover for these and other elements. This is especially true in early spring.

Use of an airplane for distributing fertilizer will aid greatly on the rougher lands. It appears likely that anhydrous ammonia, applied by the use of a combination tillage implement and gas applicator, may enter the picture. Certainly both practices will be given extensive trials on the more rolling pasture lands in the northeastern part of the United States, and they may spread over large areas farther west.

The general tendency to assume that weeds have negative value in pastures is doubtful. It is well known that they add variety of minerals and digestible nutrients to the diet. Fertilized weeds of many species make good grazing. Cows mow them down with the grass and clover. The essential point is to keep them growing luxuriantly.

The answer to the problem of tall-growing and coarse weeds lies in the regular use of a mower. Such mowings are often readily consumed by animals. They are consumed until they become moldy from rain or dew.

BARNYARD MANURE

At New Brunswick, well-fed 1,300 pound Holsteins produced manure at the rate of 21 tons annually per cow. This does not include bedding. The manure contains about 9.5 pounds of nitrogen, 3 pounds of phosphoric acid (P_2O_5), and 8 pounds of potash (K_2O) per ton. The annual output of fertilizer elements in the manure of one cow is estimated to be equivalent to one ton of 10-3-8 fertilizer. It would seem that such an amount of plant nutrients should go a long way toward maintaining fertility of the land required to produce enough feed for that cow. It seems that this would be true whether the manure was dropped directly on the soil by the cow or hauled out from the barn.

In theory, there should be little need for anything but lime and superphosphate to supplement the manure on a dairy farm. This is assuming that legumes were grown in the hay and pasture mixtures. In proportion as grain feeds are used, the picture looks still better.

But the fertility levels on the pasture soils of many dairy farms have been found to be low. Evidently much of the value of the manure contributed by cows is lost in drainage water.

PLAN THE PASTURE

Growing grass is profitable, interesting, and contagious. Modern progressive farmers have found that an abundance of high quality forage is the very foundation of any type of livestock farming.

When a pasture program is developed for a farm, there are four steps to be considered to get the best results possible.

1. Work out a sound plan and follow it carefully.
2. Lime and fertilize according to soil tests.
3. Use the proper seeding rates and mixtures.
4. Manage pastures so as to get the most from them.

The pasture plan is probably the most important single step. It is the "blueprint." It should be written down and kept on hand for reference. In working out the plan, such things as soil type, forage requirements, season-long grazing, erosion control, and land clearing should be considered.

Study the different pasture plants carefully. This insures putting each plant or combination of plants on the best adapted soil.

Lime and fertilizer are the "insurance" you buy in order that a pasture plan will succeed. Soil testing is the best method to use in determining what soil nutrients are in short supply. It also tells the kind of fertilizer and the most profitable rates of application needed.

Generally speaking, annual applications produce the greatest returns. Occasionally, it may be more feasible to provide a two- or three-year supply of lime, phosphate, and potash when land is prepared for seeding.

A complete, balanced fertilizer is recommended. For clovers and legumes heavy applications of lime, phosphate, and potash are often necessary. Even nitrogen may be added at seeding time. This is especially true if the land is poor.

For grass, heavy rates of nitrogen fertilization are almost always necessary. In addition, lime, phosphate, and potash must be present to get the best growth of grass and cereals. Even if grasses are in combination with clovers, nitrogen may still give good returns, if applied at the proper time in the growing season.

Small grains and grasses like fescue, sudangrass, millet, ryegrass, oats, and rye must have plenty of nitrogen for top production. At Stoneville, Mississippi, 240 pounds of nitrogen are recommended per year for fescue on good soil. The nitrogen should be applied in four separate applications. Big profits come from giving grasses and cereal crops all the nitrogen they can use to advantage.

Mixed fertilizers, such as 0-14-10 and 0-12-12 are becoming popular for topdressing clover and legume pastures. If plenty of "fuel" is provided, these pasture areas are ideal factories for producing grass and clover. Tests and demonstrations show that one dollar invested in pastures brings back five to nine dollars in return. The return varies with the type of plantings, soil, and management.

Proper seedbed preparation and seeding are important. The guiding principle should be getting the right crop on the right land at the right time. Fall is the best season to seed most pasture crops in the South, while both spring and fall are good in the northern areas.

Many pasture crops are started in small grain or planted in rotation with small grain. Winter grazing in the South consists of small grain, ryegrass, and fescue. They usually have a legume in them for spring grazing.

Many annual legumes, such as crimson clover and lespedeza, are being planted in oats or grass. Already, crimson clover—especially the new reseeding strains—is gaining fame as the "Belle of Southern Pastures." Ladino clover will eventually be in almost every farm program in the country. In the South, it will be ladino and tall fescue in most pasture plans. In the North, ladino also fits into many pasture mixtures. However, other grasses, like bromegrass, timothy, and orchardgrass, are used with it.

Pasture plants vary according to their needs for plant food, length of grazing period, and best grazing season. They also vary as to the type of mixture in which they are likely to do their best. A good pasture plan, therefore, will outline (1) what is to be grazed, (2) when and how it will be grazed, (3) what is to be grazed next, and (4) what to plant on the land when the old pastures are finished.

Management enables a farmer to get the most from his land in pasture. It is not hard work, but it requires constant attention. Good management makes the pasture pay off and keep paying off. This involves rotational grazing, weed control, and mowing the surplus forage.

Controlled grazing is perhaps the most important principle in

managing pastures to keep them productive. To get satisfactory returns from his labor and investment, a farmer must avoid overgrazing on any of his pastures.

BALANCE PASTURES WITH LIVESTOCK

It should not be overlooked that the value of pastures depends on a farming system that includes productive livestock. The farmer must gear together or balance (1) the development of pasture, (2) the production of supplemental feeds, and (3) the improvement and increase of livestock. The farm business may become uneconomical if any of these factors is permitted to exceed or lag behind the others.

Figure 17-2 *Gully near Sioux Falls, South Dakota, bladed in, leveled, and seeded to mixture of alfalfa, bromegrass, and sweetclover. The gullied land was converted to productive pasture.* (Soil Conservation Service Photo)

RENOVATING BLUEGRASS

According to the Iowa Agricultural Experiment Station, renovating bluegrass has come to mean introducing clover into the grass. This is done by disking or other cultivation, with the use of lime and phosphate if the soil needs them. This procedure feeds the grass roots and results in a thick, heavy sod. The vigorous grass growth largely eliminates weeds. The growth of clover provides succulent, nutritious, palatable pasturage. It is available in midsummer when bluegrass usually becomes dormant, hard, and unpalatable. Usually a good renovation job greatly increases the productivity and carrying capacity of the pasture.

The essentials of a successful renovation job seem to be the following:

1. If possible, lime in the fall before spring seeding if the soil is acid. This gives a good stand and vigorous growth of sweetclover or alfalfa. These legumes are excellent in pasture renovation seedings.
2. Disk or tear up the grass some other way in the fall if possible. Lime then becomes active immediately. This also reduces the seedbed work in the spring.
3. Apply 200 to 300 pounds of 20-per-cent superphosphate in the spring. Work it in well when preparing the seedbed.
4. Do a thorough job of tearing up the grass sod when preparing the seedbed. Don't worry about hurting the grass. It will come back quickly and better than ever.
5. Seed in the early spring or not at all. Seed not later than April 15, earlier if possible.
6. Seed a mixture of adapted legumes. The mixture most widely used in Iowa consists of five pounds of sweetclover, three of red clover and two of alsike per acre. Ten pounds of lespedeza seed are included for southern Iowa counties.

LIME HELPS PASTURES

At the Pasture Improvement Farm in southern Iowa, a series of six experimental pastures were used for several years. The production of untreated native bluegrass pastures was compared with that obtained from the same land when renovated. Comparisons were

made both with and without lime. The seeding mixture used was that already referred to as in general use. The pastures were grazed with native steers. Pounds of beef gained per acre from the various treatments for the seasons 1941 through 1943 are shown in Table 25.

TABLE 25

ACRE PRODUCTION OF BEEF ON UNTREATED PASTURES AND PASTURES RESEEDED WITH AND WITHOUT LIME

Treatment	*Average Annual Pounds Gained per Acre, 1941–43*
Untreated	108
Reseeded, without lime	143
Limed and reseeded	193

Considering both tillage and seed costs it is clear that, under these soil conditions, reseeding without the use of lime is not effective Such increase in production as was obtained on pastures reseeded without lime was due largely to the acid-tolerant Korean lespedeza. The lespedeza had some help from red clover. But where lime was included the stand and growth of all legumes were much better. Renovation, including reseeding and the use of lime, increased the average number of pounds of beef produced per acre. It was increased from 108 to 193 pounds, or approximately 80 per cent.

PHOSPHATE AIDS LEGUMES

Many farmers know that usually the growth of legumes is greatly stimulated with phosphate fertilizers.

One of the most striking discoveries on the experimental pastures at Mt. Pleasant, Iowa, was the much thicker stand and more vigorous growth of the sweetclover. This occurred on the pasture receiving 150 pounds per acre of 20 per cent superphosphate in addition to lime. The pasture was compared with one limed but not phosphated.

Beginning with the 1944 season, the bluegrass renovation experiment at Albia, Iowa, was modified to include phosphorus with lime. The sod was torn up in the fall of 1943 with a weighted spring-tooth harrow. It was thoroughly disked in the spring of 1944. At this time, 250 pounds of 20 per cent superphosphate were applied to two of the four limed pastures.

The phosphate was thoroughly mixed with the soil during the disking operation in the early spring. Two other pastures were han-

dled identically except that no phosphate fertilizer was used. The seeding mixture was the same as for preceding years. Native steers were turned into all pastures in mid-May. They remained on the pastures until about the middle of October, both in 1944 and 1945. The results, in pounds of beef per acre, are shown in Table 26.

TABLE 26

AVERAGE ANNUAL PRODUCTION IN POUNDS OF BEEF PER ACRE DURING 1944–45

Treatment	*Pounds Gained per Acre*
Untreated	105
Limed, and reseeded	147
Limed, phosphated and reseeded	155

Pasture renovation can give benefits for several years only if grazing is properly managed. A common fault is too heavy grazing in the second season following renovation. The biennial clovers then fail to reseed. Reseeding is essential to success and can only be accomplished through controlled grazing when seed heads are forming.

After the seed is developed, the pastures can be grazed heavily the remainder of the season and into the fall. The accumulated growth of grass and clover can be removed from the surface by winter. This close grazing permits the legume seed to be shattered and brought in close contact with the soil. It also weakens the grass so that its competition with the seedling legumes the following spring is reduced. This is desirable.

SOLVE RENOVATION PROBLEMS

Some farmers have had difficulty in maintaining good stands of clover in bluegrass pastures over a period of years. Experienced, observant livestock men are overcoming this difficulty. They are doing it through good grazing management. There are renovated pastures in various parts of Iowa that have good stands of sweetclover in the grass six and seven years after seeding.

Pastures closely grazed all season show a rather weak sod. They can be prepared for the renovation process without excessive disking or other cultivation. When the bluegrass sod is thick and heavy, the cost of preparing the seedbed is excessive. The disk is used almost exclusively in Iowa in pasture renovation. This is, however, not because it is the only available tool thought suitable.

Some farmers know that several implements are better for renovation than the disk. Shallow plowing to set back the grass and give the clover a chance to become established is preferred in some areas. Plowing also helps control weeds. Tractor-mounted corn cultivators and subsurface tillers have given excellent results.

Four methods of seedbed preparation were compared at Albia in 1945. These included (1) disking, (2) shallow fall plowing, (3) shallow spring plowing, and (4) tilling with a rigid, mounted, subsurface tiller, especially constructed for the purpose. The sod was heavy and dense.

The fall plowing was to about a four-inch depth in mid-November. The spring plowing was done the last of March at about the same depth. Fall-plowed plots were left rough over the winter. The result was little or no erosion. The plowed plots were disked twice with a tandem disk. This was done just before seeding on March 28. The subtilled plot was disked twice in the spring with a tandem disk and the disked plot four times.

The degree to which bluegrass was set back or killed varied greatly between the different treatments. The grass was almost entirely killed on the fall-plowed plots. The average stand of clover obtained on these plots was estimated at 96 per cent. Considerable bluegrass came back on the spring-plowed plots. The average stand of clover seedings was 78 per cent on these plots. Kentucky bluegrass came back strong and vigorous, both on the disked plots and on those subtilled and disked. Clover stands on these plots averaged 65 and 59 per cent, respectively.

Seeding mixtures compared on each of the plots receiving different tillage treatments included (1) a mixture of five pounds of sweetclover, three of red clover, and two of alsike; (2) ladino clover, four pounds per acre; (3) birdsfoot trefoil, six pounds per acre; and (4) bromegrass, eight, and alfalfa, ten pounds per acre.

The clover mixture produced the heaviest growth in the first, or seeding year. The ladino clover also made a heavy, vigorous growth, particularly late in the season. The birdsfoot trefoil characteristically made very little growth the first year. This was particularly true on the plots where bluegrass had not been sufficiently killed back.

The bromegrass-alfalfa combination made an exceptionally good growth on the plots plowed in the fall. This killed the bluegrass out. The conversion of bluegrass pasture to a bromegrass-alfalfa pasture

appears to be a relatively simple job. Changing bluegrass pasture into a bromegrass-alfalfa pasture seems to be a desirable step. It also is feasible on many farms.

LONG ROTATION PASTURES

Many pastures left permanently in bluegrass would be helped by cultivation if it can be done without erosion. Such pastures can be plowed and put into corn for one year. At the end of the year, the field would be seeded to bromegrass-alfalfa with oats. Such a seeding should remain productive for several years. After, if it becomes sod-bound, it can again be plowed and another crop of corn produced while re-establishing the brome-alfalfa. The grass portions of such fields that cannot or should not be plowed are allowed to grow up during the year. They are grazed in the early winter after corn has been harvested.

PERMANENT PASTURES

Because of steepness or of trees, rocks, or ditches, some pastures cannot be plowed. They must be left permanently in bluegrass. Often such pastures are badly infested with weeds and brush. They produce little feed. In every case, these pastures can be made more productive by mowing. Mowing controls weeds and brush which rob the soil and grass of needed moisture and nutrients.

MOW BRUSH AND WEEDS

Perennial weeds can best be controlled by mowing. Mow when in the bud stage, usually early July. Pastures with perennial weeds need to be mowed several seasons to eliminate them. Annual weeds, such as ragweed, are easily controlled by mowing before they have made seed.

Buckbrush has become a serious problem on many pastures. This shrub can be controlled by mowing once each summer. The most difficult job is removing the first heavy growth. The growth in succeeding years can easily be mowed with an ordinary horse-drawn mower. Surprisingly heavy brush can be mowed with a power take-off mower. The tractor should be operated in low gear to produce speed on the sickle.

Annual mowing of pastures should become a general practice because it greatly improves production.

Figure 17-3 Broomsedge sod in Ohio being prepared for planting to pasture by the trash mulch method Seeding is done in the trash (Soil Conservation Service Photo)

NEW AND BETTER PASTURE CROPS

The list of new and improved varieties of forage crops is increasing The superior southern types of bromegrass Fischer, Lincoln, and Achenbach- are already finding a permanent place on many farms The Ranger and Buffalo varieties of alfalfa, highly resistant to bacterial wilt, will have an important bearing on use of alfalfa in seedings with bromegrass for hay and pasture

Other new forage varieties are just around the corner These include such varieties as I 6 and I 39 lespedezas, Madrid sweetclover, Emerson red clover, Ioreed canary grass, ladino clover, and birdsfoot trefoil All of these are giving promising results in pasture seedings

TRASH MULCH SEEDING

The trash mulch method of reclaiming or rejuvenating idle, unproductive land with legumes and grasses fills a definite need It is particularly well adapted to the hilly sections of Ohio and similar areas elsewhere This was shown by practical field tests conducted in sixteen counties in southern Ohio from 1944 through 1948. The

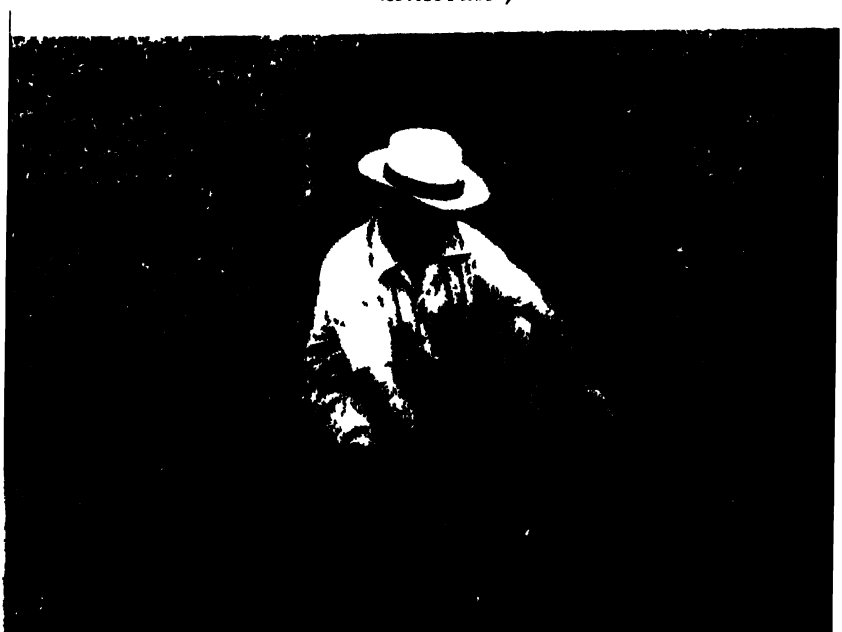
trash mulch method of preparation means working up the land with some implement that leaves the plant residues on the surface. The trash is not buried as with ordinary plowing. The trials were located on private farms. In all, there were ninety tests on nineteen soil types.

The trash mulch method of seeding is particularly desirable on slopes too steep to plow. A fairly wide range of slopes was covered by the trials. Some seedings were made on level land. Nearly one half of the seedings were made on idle land. Some of the areas had not been cropped for twenty years.

An equal number of test seedings were made on pasture land. In many cases, it was equally as unproductive as the idle land. Some trials were made on old meadows. The trials were inspected each year and rated as excellent, good, fair, or poor.

Of the tests, 81 were classed as successful at the end of the first season. There were 19 excellent, 27 good, 22 fair, 13 poor, and 9 failures. At the end of the second season, some three or four of those previously called failures were rated as successful. Yields of two to three tons per acre of high quality legume-grass hay were obtained

Figure 17-4. Weeping lovegrass seeded directly in cane stubble without any seedbed preparation, Caddo County, Oklahoma. (Soil Conservation Service Photo)



on areas used for hay. Other areas provided many days of summer pasture.

The results of the field trials indicated (1) the trash mulch method is a good erosion-control practice. It is especially valuable in establishing legumes and grasses on idle or unproductive fields. Erosion would be serious if they were plowed and prepared the usual way. (2) With the use of adequate fertilizer and lime, eroded and unproductive hill lands of Ohio produce profitable crops of grass and legumes, including alfalfa. (3) Sowing grasses and legumes, including alfalfa, is a logical first step in restoring the productivity of eroded and unproductive hill land.

Failures or poor stands were the result of (1) inadequate preparation (chief cause), (2) lack of lime or fertilizer, and (3) improper seeding methods.

Seeding is advantageous on sloping land for several reasons. Foremost is its erosion-control value. The trash intercepts falling raindrops. This preserves the open structure of the surface soil layer. The porous soil takes in much of the rain and little if any runoff occurs. Infiltration of most of the rainfall makes for a good supply of moisture for the seeding.

The trashy surface also reduces evaporation. This improves soil moisture conditions. Also, most unproductive soils are low in organic matter. When plant trash is left on the surface it is beneficial in other ways too. It increases the efficiency of fertilizer. It preserves and increases the organic matter of the soil. It results in a productive soil. It makes soil more favorable for the growth of grassland legume seedlings.

WHERE TO USE THE METHOD

The trash mulch seeding method can be used on (1) idle or unproductive hill land where there is grass vegetation worthless as a feed, (2) on other hill land where improved grass and legume production is desired, and (3) on similar areas where a change in species of vegetation is desired.

In the first category are idle areas covered with broomsedge, poverty grass, weeds, briars, and even thorn bushes. Usually such land is too low in fertility for general cropping.

In the second category are areas now called pasture land, where the desirable grass species are thin and lacking in vigor. If such areas

have a fair percentage of bluegrass, they may be improved with the least cost. Liming and fertilizing bring low-cost improvement. If there is urgent need for increased production in the shortest time, trash mulching is desirable. Within a year's time, trash-mulched land often will be near full production.

The third situation may be somewhat like the second except that a different type of forage is desired. Many hill farms need additional hay. They also need hay-type summer pasture. This need is often met by dual-purpose meadows. Occasionally a farm has more permanent pasture than can be used to best advantage. Converting a part of this to a dual-purpose meadow is to advantage.

WHEN TO WORK THE GROUND

Spring seedings are generally recommended. It is best to apply the lime and start working the ground the previous fall. Complete the preparation in early spring and make the seeding. Doing some of the work the previous fall enables one to sow early in the spring. The soil should be dry enough to work into a good seedbed. Although early seeding is recommended, many successful seedings have been made well into May. Generally, the later the seeding, the greater the risk.

Many successful summer seedings have also been made. The trash mulch method practically eliminates erosion. It also increases the amount of moisture in the soil. This is done by increasing the amount of water absorbed by the soil and by reducing evaporation losses.

HOW TO WORK THE GROUND

The first step in working the ground is the addition of lime. The amount applied is more important than method of application. Have the soil tested. Apply enough lime to bring the soil reaction up to slightly below or to neutral, depending on the plants to be sown. If ladino clover or birdsfoot trefoil is to be sown, soil can be slightly on the acid side. If alfalfa is sown, soil should be neutral. As previously pointed out, it is desirable to apply lime during the fall before the spring seeding.

Work up the old vegetation with a heavy disk, field cultivator, or similar tool. A rotary tiller may be used if available. If an ordinary farm disk is used, it should be weighted with several hundred pounds. Stone, sand, or other heavy material may be used for weight.

Weighting is particularly necessary if the old vegetation is dense.

Ordinary farm disks, heavy disks, disk tillers, or one-way disks, cutaway disks, field cultivators, rototillers, and even horse-drawn cultivators are used. A heavy disk, either offset or straight, or the one-way disk tiller do the job most rapidly. But they require considerable power and may cut too deeply. The one-way is a bit difficult to handle on steep slopes. On the whole, an implement like the field cultivator does the job most satisfactorily. But, if the old sod is heavy, this implement may leave the field rough. Disking may be needed to finish the seedbed.

The preparation should be sufficient to make a fairly smooth, but not necessarily a finely worked, seedbed. In fields where there is a fair sod of cultivated grasses, working up with a disk or cultivator-type implement may be difficult. It may be impossible to kill out the old grasses. Shallow plowing is recommended on such areas.

A word of caution is needed, however. Many are inclined to think they are not plowing right unless they cut a good, deep furrow. A furrow slice three inches or less, disked thoroughly, makes a good trash mulch seedbed. Cultipacking before seeding is a good practice. It is not so essential as cultipacking *after* seeding, however.

BROADCAST SEED

Of the various methods of seeding that have been tried, broadcasting after, or at the time the fertilizer is drilled, is recommended. Arranging the seeder spouts to put the seed in back of the disk is a method of broadcasting.

Drilling usually puts the seed too deep. Band seeding has been tried but is not recommended. This method requires a fine, smooth seedbed.

FERTILIZE LIBERALLY

Many successful seedings have been made with an application of 400 pounds of fertilizer. An additional application of from 400 to 600 pounds per acre of 0-20-10 is desirable. An accidental application of 1,000 pounds of 0-12-12 gave an excellent meadow.

Some excellent seedings have been made using a complete fertilizer. Often a fertilizer carrying only a small amount of nitrogen is advisable. Nitrogen may stimulate surviving grasses which, in turn, may provide undue competition for the legumes. This is particularly

true if there is some bluegrass in the field. Topdressing grass and legumes in the years following seeding sometimes is a must. This is particularly true on soils that do not store potash.

USE GRASS-LEGUME MIXTURES

A good spring seeding mixture for hay or summer pasture is: alfalfa, six to ten pounds; ladino clover, one quarter to one pound; and timothy, six pounds, or bromegrass, eight pounds. For summer seeding cut timothy in half. For an all-season pasture for continuous grazing, the alfalfa may be omitted. Even though the alfalfa goes out in a year or so under this management, there are advantages in including it. The deep roots of the alfalfa add materially to the value of the seeding in rebuilding the soil. Alfalfa also materially increases the early production from the field. For an all-season, long-life pasture, birdsfoot trefoil bids fair to be the best legume. The seeding rate is three to four pounds per acre. Inoculation of birdsfoot trefoil and alfalfa is essential.

Clip new seedings once or twice the first season to remove weeds. The field may appear weedy and even unpromising until clipped. Grazing may be substituted for clipping, if controlled. In favorable seasons, some hay may be made the first season If so, cut before September.

PASTURES FOR THE SOUTH

Because of mild, open winters, pastures can be utilized over a larger part of the year in the South than in the Corn Belt. There is also a wider variety of pasture plants to choose from in the South.

The Soil Conservation Service Research Station at Watkinsville, Georgia, conducted extensive pasture studies over a period of years. The purpose was to develop suitable pasture mixtures for a wide variety of soil conditions.

For bottomlands, a mixture of Bermuda grass, Dallis grass, and white Dutch clover was satisfactory. Pastures consisting of this mixture supply grazing for seven months—April through October. They have a carrying capacity of one cow unit per acre during this period.

Kudzu makes an excellent pasture plant for steep hillsides and badly eroded and gullied areas. It grows luxuriantly in the Southern Piedmont. With moderate fertilization and little care it covers steep

Figure 17-5. Eroded and abandoned land in Georgia. A worn-out portion of a farm formerly used for row crops. Kudzu protects the soil from erosion and provides excellent grazing. (Soil Conservation Service Photo)

eroded and gullied hillsides with succulent and palatable herbage. Kudzu is rich in feed nutrients. It is a heavy mulch producer. Each year it lays down a mat of dead leaves to cover the ground and protect the soil.

Established on critical areas, kudzu conserves soil and water better than any other known plant. Its extensive root system reaches deep into the subsoil. This makes it practically drought-proof.

Wherever kudzu grows, it builds up the soil. It adds organic matter and nitrogen. Fenced in for controlled grazing, it is insurance against drought in summer and fall. It remains palatable and is relished by cattle when grass in summer pastures gets old and tough. If not overgrazed, it soon renews its top growth.

Kudzu can be grazed down in the fall and followed by winter annual grasses and legumes. Kudzu provides a "trashy" but rich seedbed after disk harrowing preparations.

Some reseeding types of winter annuals do well following kudzu. Among these are ryegrass, rescuegrass, vetch, and Caley peas. Oats make rapid growth when sown in disked kudzu pastures.

Tall fescue, fall-sown in disked pastures, does well in kudzu. It

produces valuable winter grazing after the kudzu tops die down at frost. Kudzu must be control-grazed during the summer. This prevents shading out of the grass.

In the spring, kudzu pastures should be closed for about two months. This permits the winter annuals to mature seed. The dead plants add more "plant manure" to what was originally poor, eroded soil. The new growth of kudzu becomes well established again by June. Kudzu produced up to four and a half tons per acre of dry hay. Of this, three tons were pasturable at critical times of the year.

Sericea, a perennial lespedeza, is sometimes called "poor land alfalfa." Like kudzu, it has the ability to make a dense stand on poor land when fertilized and given a little care. It is a mulch producer and a soil-improving legume unless mowed too frequently or grazed too heavily. It also produces valuable seed crops that can be combine-harvested. After its first year of growth, it may be utilized for warm-season grazing - April to October.

Young shoots of sericea are tender and palatable. As the stalks exceed twelve to fifteen inches in height, the foliage becomes somewhat bitter. It is less palatable because of increasing tannin content. Early and consistent grazing, or clipping the taller growth until early fall, keeps the pasture in good condition. This controls weeds too. Plants should be allowed to make late fall growth. This maintains vigor and stand.

Sericea pastures may be oversown to winter annuals (burclover, crimson clover, and ryegrass) on a disk harrowed seedbed. Perennial cool-weather grasses (tall fescues and orchardgrass) may also be used. Once established, no further tillage appears necessary. This provides a summer perennial legume and cool-weather perennial grass in combination on the same land. One makes its best growth when the other is relatively inactive. If necessary, controlled grazing or special nitrogen fertilizer treatment may be used to stimulate the grass. Lime, phosphate, and potassium may be used also.

Both kudzu and sericea are exceedingly valuable plants to use on poor, eroded lands. They supply the initial buildup needed to prepare the land for other valuable plants that require improved land.

To meet the need for more winter grazing crops, a separate upland pasture should be designed. It should contain oats, reseeding crimson clover, and ryegrass for winter grazing. Crabgrass and Bermuda take over for a short time during mid-summer. This pasture requires a heavy disk harrowing. The harrowing is generally made

in late August. It should follow a rain, which softens the sod. Oats are drilled; clover and ryegrass volunteer. Spring is the flush grazing season, so this pasture should be closed about April 15. A combine-harvest of clover seed can be made about June 1. This makes a good early winter pasture. It produces in excess of five tons per acre of hay-equivalent grazing in addition to the clover seed crop.

Once the rather dry fall period is past, adequate rains can be expected during the winter. This climatic condition makes it practical to use moisture-loving, cool-weather growers on fertile, well-drained upland soils. These should be control-grazed during the winter.

When making disk-harrowed seedbeds on eroded upland soil in the fall prior to seeding winter annual pasture mixtures, it is good practice (1) to apply complete fertilizer annually and lime every five years, (2) to use grass-legume mixtures, (3) *never* to graze the top growth closer than three or four inches, and (4) avoid grazing when the ground is soggy.

Overgrazing is especially bad practice during the winter. All plants require warmth and sunshine for good growth. Cool-weather growers are no exception. In addition to a root system, they must have foliage. This enables them to respond quickly to temperatures that stimulate growth during mild spells. During the winter sunshine is reduced because the sun is low on the horizon; days are short. Cloudiness and long, slow rainy periods further limit plant growth. Occasional cold snaps and freezes stop plant growth. Overgrazing seriously interferes with plant growth under these conditions.

Overgrazing is poor practice at any time of the year. It increases runoff and erosion. It shortens the life and reduces the vigor of the sod plants and reduces the total amount of feed produced. Overgrazing also robs the soil of fertility. Fertility is otherwise built up in well-managed pastures.

Other pasture plantings that show real promise are (1) oats and annual lespedeza with biennial sweetclover, (2) orchardgrass with ladino and reseeding crimson clover, (3) sericea and orchardgrass, and (4) tall fescues with ladino clover, Kobe lespedeza, sweetclover, or alfalfa.

Upland pastures should be developed on land with prior conditioning. Kudzu, sericea, or rotations based on annual lespedezas should be used to condition the land. Adequate amounts of fertilizer

and lime should be applied. This procedure offers minimum difficulty in securing good stands and growth of small-seeded pasture plants. These plants usually are difficult to establish on eroded cropland low in organic matter.

Questions

1. What important change is taking place in our system of farming? What is the cause of this change?
2. What is grassland farming? How does it differ from row crop farming?
3. What are we finding out about the use of fertilizer on pasture? What are some other good pasture practices?
4. What effects do legumes have on the potassium supply of the soil? Which is the best season to fertilize pastures?
5. Are weeds always harmful in pastures?
6. What becomes of most of the manure produced on farms? Are legumes a dependable source for nitrogen for other crops?
7. What are the main steps in developing a sound pasture program?
8. What are the main steps in renovation pastures?
9. What is meant by trash mulch seeding? How do you seed pastures by the trash mulch method?
10. What are the main pasture grasses in the south? In the Corn Belt? In New England?

18

Protect the Soil and Improve the Range

THE chief cause of soil deterioration on grazing land is the loss of plant cover. The plant cover is destroyed by overgrazing and poor land management practices, exposing the ground to wind and rain The impact of falling raindrops causes soil splash, puddle and fertility erosion, heavy runoff, and other damage.

The quickest, most effective, cheapest way to restore the range is by the use of the range practice best suited to the operation involved. Range practices should be effectively coordinated with natural growth habits and requirements of the principal forage plants.

The state of health or productivity of a range is known as the "range condition." Range condition never remains unchanged for long. It is either improving or deteriorating. Range deterioration is the effect of a downward trend of condition. The destruction of plant cover brings about deterioration of soil. Range restoration means stopping deterioration and bringing about an upward trend. This changes it from an unsatisfactory to a satisfactory condition. Four range condition classes are recognized: excellent, good, fair, and poor.

In any climate there are many kinds of soils. On a given soil may be found vegetation types representing climax or varying degrees of departure from climax. An area that is uniform with respect to climatic and soil conditions is called a "site." Differences between sites

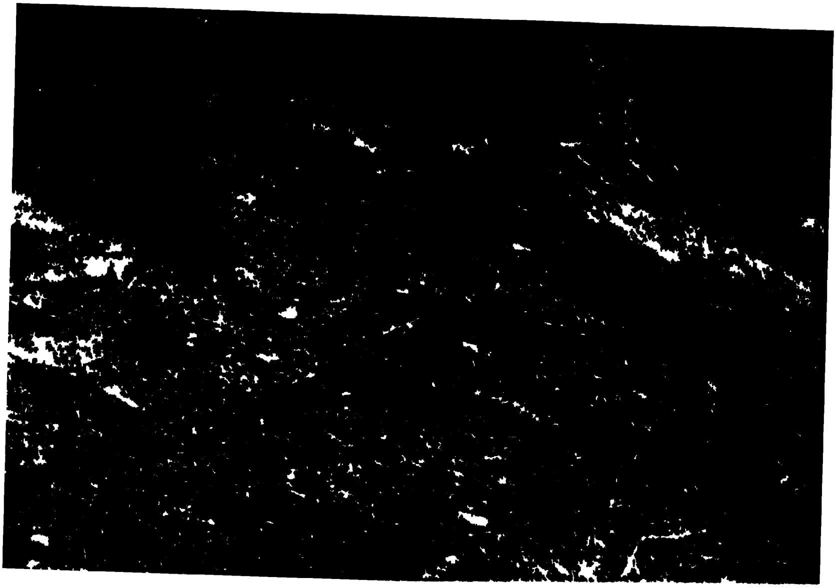


Figure 18 1 The litter on this Pennsylvania woodland was destroyed by overgrazing. This exposed the bare ground to the impact of the large drops of water falling from the tips of the leaves during rains. Severe erosion was the result. (Soil Conservation Service Photo)

are best measured by differences in climax vegetation.

Even in each condition class, there may be a rather wide variation. There may be variation in density, composition and vigor of forage plants. Each range has its own top condition. Therefore ranges must be classified in terms of their own best possible development as well as kind of plant cover and forage production. For example, a mountain meadow naturally has a higher rainfall, deeper, richer soil, a thicker plant cover, and much greater forage growth than semidesert grassland. This is true even when both are in satisfactory condition. Hence, a mountain meadow cannot be judged by the standards used for a desert grassland.

Overgrazing is responsible for much of the soil destruction on grazed woodlands. It is the litter on the ground, not the foliage on the trees, that provides the effective control of soil splash caused by falling raindrops. Actually, erosion may be more severe on wooded areas than on adjacent unprotected nonwooded areas. This is true where the ground is kept free of litter and other low-lying plant cover.

The effect of removal of ground cover can be observed with indi

vidual trees. The foliage of the trees intercepts the falling raindrops. The water is formed into larger drops before it drops off the tips of the leaves. When they strike the ground these larger drops are more destructive. They splash more soil than drops falling directly as rain. The result is more damage if ground cover has been removed.

CORRECT GRAZING MANAGEMENT PROTECTS THE SOIL

Certain combinations of plants determine range condition on any range site. It is only when a range is managed so as to build up plant vigor that we expect the combination of plants known as climax vegetation to become established. This is accompanied by returning organic matter to the soil and producing an excellent range condition. The soil on excellent range usually is darker in color than it is on poor range. This is because the soil contains organic matter—living and dead plant matter, animal life, and humus. It has more plant litter on the surface. The decay of this litter and the formation of humus improves the soil structure. Improved soil structure increases the soil's ability to take in and hold more water for plants to use.

Figure 18.2. On woodlands it is the litter on the ground and not the foliage on the trees that controls splash erosion. This view was taken in Spokane County, Washington. (Soil Conservation Service Photo)

In contrast, the soil on poorly managed ranges is more compact at the surface. It is less capable of taking in water. It supports less vigorous plant growth. It has less litter on the surface. It is subject to more severe damage from raindrop splash.

Both depth of soil and soil texture have a bearing on the amount of moisture the soil can take in and hold. It takes two to three inches of water to wet a fine-textured soil to about one foot in depth. On the other hand, a coarse-textured soil requires less than an inch of water to wet it a foot down. The finer the soil, the greater the holding surface for film moisture.

RANGE CONDITION AFFECTS WATER ABSORPTION BY SOIL

The sparse growth of grass on ranges in poor condition is due to two factors One is the lack of soil moisture. The other is the weakening of plants by too-heavy grazing. The surface of the ground becomes sealed. The water runs off the surface as off a roof. The ease with which rain enters the soil and is available to plants is an important factor in grass growth. Sometimes it is more important than the amount of rainfall. Just after a rain is a splendid time to show how range condition makes a big difference in moisture infiltration. A good place to make a comparison is where a fence divides ranges of different condition classes. Holes can be dug to determine the depth of moisture penetration.

In May 1948, after a two-inch rain at Marfa, Texas, Soil Conservation Service range specialists and a group of ranchers checked a site. A fence divided a range in good condition from one in fair condition. They found that the soil on the range in good condition was wet to a depth of thirty inches. Across the fence, the same amount of rain penetrated the soil only two inches. Three weeks later, the grass on the range in good condition was heading out. The grass on the other side of the fence had grown up about two inches and then "burned up" for lack of moisture.

Information was collected in 1947 in each of the four range condition classes on a rolling hill site in western Texas. This showed the relationship of range conditions, forage production, soil structure, and temperature and rate of water intake. Range condition classes are based largely on the kinds of plants making up the forage cover. Current cover is compared with the climax vegetation for the site. The most valuable plants occur on ranges in excellent condition.

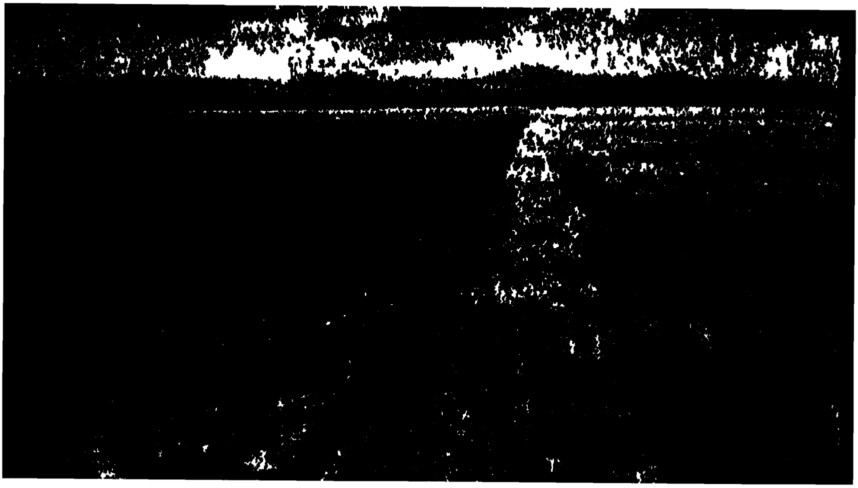


Figure 18-3. *Sparse plant cover on the severely overgrazed range at the left of this Jeff Davis County, Texas, ranch provides less protection from the impact of the falling raindrop than the cover to the right. Less water penetrates the soil where there is little plant cover than where there is ample cover to protect the soil against the falling raindrop.* (Soil Conservation Service Photo)

The least valuable plants predominate on ranges in poor condition.

Analysis of these soils showed the per cent of organic matter in the soil by range condition class, as follows:

Excellent condition	4.6%
Good condition	3.8%
Fair condition	3.6%
Poor condition	2.1%

The amount of litter and vegetation on these soils had a great influence on surface soil temperatures. Soil temperature in turn affected the temperature in the surface layer of soil. Temperature readings in the surface layer of soil on these range lands in August, with an atmospheric temperature of 90°, were:

Excellent condition	104° Fahrenheit
Good condition	110° Fahrenheit
Fair condition	114° Fahrenheit
Poor condition	120° Fahrenheit

Moisture loss from evaporation increases as soil temperatures increase. High temperatures reduce the amount of moisture available

for plant growth. The high temperature of the soils on ranges in poor condition also affects the plants directly. Thus, the cover not only breaks the force of the raindrops but also helps to keep soil temperatures down.

The rate of intake of water on the same soil was determined by the amount of plant cover on the ground. The rate of infiltration or intake of water was in proportion to the amount of cover. The greater the amount of cover the higher the infiltration. Surface cover and soil conditions accounted for the different water intake capacities in the same soil.

Permanent characteristics of the soil, like texture, exerted less influence on the amount of water lost or held than did the differences in cover and soil conditions within the same site. However, water losses were always high on very shallow soils. This was true regardless of cover or soil condition.

The tests consisted of twenty-minute applications of two inches of water to twelve- by eighteen-inch plots. The plots were selected to represent different cover conditions. The water was applied in the form of falling drops of controlled size and velocity. It was applied by a raindrop applicator mounted on a truck. Water and soil leaving the plot either as splash or runoff were collected and measured. This showed the comparative effectiveness of the cover in preventing splash and water loss.

The degree to which structure within the same soil may vary with cover conditions in response to past use of the range was determined. The effect of these conditions on water intake was also determined. A series of three plots, having a medium-textured surface soil with a tough clay a few inches below, were used. They lost 21 per cent, 59 per cent, and 63 per cent of the water applied in the test.

The plot which absorbed the most water was in fair condition. It had not been grazed for several years. It was covered with a dense stand of vine-mesquite grass. The grass provided 10,605 pounds of cover per acre. Only 21 per cent of the water applied ran off. The other 79 per cent was absorbed by the soil. The soil had a porous granular structure. It withstood the impact of water drops during the test. This permitted free percolation of water into the soil.

Another plot was in poor condition. It was formerly a cultivated area. Although lightly grazed at the time of the test, it lost 59 per cent of the water applied even though it had 3,520 pounds of plant cover per acre. The soil was densely compacted to a depth of from one to one and a half inches.

The third plot was in a cultivated field. The field had been plowed and prepared for planting a few weeks before. Young winter peas provided 1,082 pounds of cover per acre. This plot lost 63 per cent of the water applied. Although the soil was more porous than the preceding plot when the test began, drops of water striking the surface quickly sealed it over. This prevented the entry of water.

EFFECTIVENESS OF COVER

The effectiveness of cover in preventing splash erosion is in proportion to the amount of cover present when the rain falls. There are two factors that determine the effectiveness of cover. One is the thoroughness with which the land surface is covered. The other is the weight or bulk of the cover present. Thoroughness of cover determines how well the ground is protected from raindrop impact. Weight or bulk of cover determines how well raindrop energy is absorbed.

The *amount* of cover in providing protection from raindrop impact is more important than the type of plants, range conditions, degree of use, kind of crop, or other variables. The effectiveness of cover in reducing soil splash increased as the amount of cover increased until complete protection was provided. Beyond this point additional cover had no further effect.

Differences in growth form of the cover had some influence on its effectiveness. These differences resulted mainly from varying quantities of cover produced by different grasses. Differences were generally lost in the mixtures that make up range types.

All range plants were compared to show effectiveness in reducing erosion from splash in relation to the amount of cover. On the basis of effectiveness, the different factors measured ranged in the following order: (1) soil coverage, (2) weight of total cover, (3) forage density, and (4) average height.

The completeness of soil *coverage* was the factor most closely related to effectiveness in absorbing the impact of rain.

The total *weight* of cover was an almost equally reliable measure of its protective value. Weight of cover can be more easily measured than per cent of cover. Weight, therefore, is used as the standard expression of amount of cover.

The *density* of the living stand of plants and average *height* of the standing forage provide a rough indication of the effectiveness of the cover in reducing erosion by splash. There was wide variation

from the general trend as determined for either measurement. In either case, the measure reflected in a general way the amount of cover present, but did not take account of the litter on the ground.

The rather wide range in effectiveness of the same amount of cover suggested that more than one feature might have a bearing on the results. Two combinations of the above measurements gave closer comparisons than either of the single measurements on which they were based.

This indicated that effectiveness of cover was best indicated by a dual measurement. The dual measurement reflects a combination of total weight and soil coverage The product of these two measurements was used as an index of "effective weight."

By this index, 2.000 pounds per acre of forage and litter covering 50 per cent of the soil surface would have the same value as 4,000 pounds per acre covering 25 per cent of the surface. Both covers would have an "effective weight" of 1,000 pounds per acre. They would reduce erosion from splash by approximately 90 per cent.

AMOUNTS OF COVER REQUIRED

These results indicate the usual or average amount of cover required for any degree of control of soil erosion by splash, regardless of how the amount of cover is estimated.

On the basis of soil-protection values, range plants and field crops can be grouped into three growth-form classes They are (1) ordinary crops and grasses, (2) short sod grasses, and (3) tall crops and weeds.

Curves were plotted showing the average effectivenss of each growth form in relation to total weight of cover. A fourth curve represents the average value of mixtures of species of different growth forms found in the range vegetation judged. These curves are similar in form.

Different degrees of effectiveness of the same amounts of cover of different growth forms reflect the natural arrangement of the foliage characteristic of each growth form. These differences rapidly disappear with increasing amounts of cover as effectiveness approaches 100 per cent. Tall, coarse crops and weeds are not completely effective in any amount. This is due to a certain amount of splash caused by drops falling from the foliage. These drops fall more than two or three feet after being intercepted and so are more damaging.

Effective weight takes into account both the degree of surface

coverage and the total weight of the cover. It is especially useful in judging cover of unusual growth form or irregular distribution on the ground. When the plant materials are of average form, either weight or coverage alone is a satisfactory indicator of effectiveness in preventing splash. By average form is meant the grains, fine-stemmed legumes, or mid-grasses, uniformly spread over the ground.

The effectiveness of cover in reducing erosion by splash is characteristic of the cover itself. It is completely independent of the soil on which the cover occurs. These values should be applicable to any example of forage cover on any site and in any rain. Table 27 summarizes these results in terms of average amounts of cover required to provide different degrees of effectiveness in controlling soil splash.

TABLE 27

AMOUNTS OF COVER REQUIRED TO CONTROL EROSION BY RAINDROPS
AVERAGE AMOUNTS FOR DIFFERENT DEGREES OF EFFECTIVENESS

		Total Weight of Cover			
Effectiveness	*Effective Weight of Cover**	*Short Sod Grasses*	*Mixed Range Grasses*	*Ordinary Crops and Grasses*	*Tall, Coarse Crops and Weeds*
(per cent)	(lb./ac.)	(lb./ac.)	(lb./ac.)	(lb./ac.)	(lb./ac.)
96	3,000	4,000	5,000	6,000	
97	2,500	3,000	3,750	5,000	
95	1,500†	2,000	3,000	3,500	6,000
90	1,000	1,500	2,000	2,500	4,000
85	750	1,200	1,600	2,000	3,000
80	600	1,000	1,400	1,750	2,250
75	500	850	1,200	1,500	1,800
70	400	700	1,100	1,300	1,500
60	300	500	900	1,000	1,100
50	200	400	750	800	900
35	100	250	500	600	600
25	50	125	400	400	400

* Total weight (lb./ac.) × coverage (per cent).
† 2,000 lb./ac. for tall, coarse crops and weeds. Cover of this growth form ordinarily does not exceed 96 per cent effectiveness, attained when effective weight is 3,000 lb./ac.

RANGELAND

Western rangelands in the United States are usually arid. They often have shallow or salty soils and steep topography. Rainfall varies from four to thirty inches per year, but less than fifteen inches over a large area. Evaporation rates and summer temperatures are high. These conditions frequently result in sparse plants and low grazing capacity.

This lack of moisture makes proper grazing fundamentally important. If plant stability is destroyed, soil erosion may increase rapidly. Once exhausted and eroded, rangeland returns to normal only after years of reduced use. With proper management some ranges may recover within ten to fifteen years. Sometimes fifty to a hundred years or longer may be necessary. Unfavorable plant succession results from excess livestock numbers. It is generally believed that ranch income is influenced more by numbers than by any other factor. As a result, operators strive for maximum numbers. They risk range destruction. Thus, knowing range grazing capacity is very important.

Characteristically, livestock operations are large Tremendous areas are involved. Fencing of small areas generally is uneconomical. It is not always possible to know the exact area from which forage is obtained.

Seasonal migration is common in the mountainous area and on public lands. On these lands range animals move to higher elevations in the summer and to lower elevations in the winter. However, yearlong use is the rule in the Great Plains throughout the year without supplemental feed. Supplemental feed may be added during severe storms or just preceding calving and lambing time. Grazing time is not readily varied as a management practice. Supplemental feeding is often impractical or uneconomical. As a result grazing intensity on the range is usually determined mainly by numbers of animals alone. Adjustment to current forage production is difficult at best.

RANGE CONDITION CLASSIFICATION

At one time range students judged ranges on the basis of indicator plants. Such characteristics as density, vigor, reproduction, and plant age–classes of the species composing the native plants were used to determine trend and deviation from normal or climax. Where stocking history was known, estimation of correct stocking was based on these factors. More recently plant composition has been used as the main clue to range condition.

The older method served as a basis for attempts at a more organized analysis, termed condition classification. Deviation from normal is classed in one of four categories: from Class 1, which is virtually climax, to Class 4, which is dominated almost entirely by invading species. All characteristics may be considered at once, or separate

classifications may be made for species composition, soil erosion, reproduction, and vegetation density.

Attempts have been made to interpret such data directly into grazing capacity. Again, knowledge must be based on ranges of known capabilities. Thus, if a Class 2 sagebrush range is known to yield twenty animal days per acre, it is assumed that other Class 2 sagebrush ranges of similar nature will do likewise.

This method raises several objections. Among these are that it assumes knowledge of climax or normal condition. It is not always possible for inexperienced people to determine the climax with reasonable assurance. There is also the question as to whether climax is the most desirable condition. Perhaps it is an uneconomical goal. Because of the number of factors involved, this method is too complicated for practical use.

On the other hand, the plant composition method contains only one factor. It is simple, direct, and easily applied. And, too, plant composition reflects the sum of the effects of all factors influencing a given site. It accurately indicates the stage in the plant succession scale. Anyone familiar with those factors can tell how good the range is.

Plant composition is the primary clue to range condition. Other factors are useful also in evaluating trends in range condition. Some of the most important of these are plant density, vigor, soil tilth, erosion, livestock gains, and calving percentage.

It is usually true that ranges in the top condition class generally have better stands of plants than ranges in lower condition classes Much depends on the species of plants making up the range forage. A range forage having a high percentage of climax species may be more valuable even at lower densities than one with a high density composed mostly of invading species. Important changes in stand or density of vegetation aid in determining whether the trend is moving upward or downward.

Like density, vigor can be a valuable aid in determining range condition if it is properly understood. High vigor indicates the plants are improving in growth. But vigor alone gives no clue to the range condition. Range vegetation may be of high vigor on any range condition if the range is properly stocked.

The condition and amount of litter indicates whether a range is improving or deteriorating. If litter is accumulating it is usually safe to assume the range is improving. The converse is also true. How-

ever, the amount of litter alone is not a safe basis on which to judge range condition A properly grazed poor-condition range consisting mostly of invaders may have an abundance of litter

Active erosion is usually associated with inadequate plant cover. Likewise, erosion scars usually are found where the total plant cover is increasing The absence of erosion does not necessarily indicate good or excellent condition The plant cover may be composed mostly of annuals It is generally true that ranges in excellent or good condition are less apt to erode than those in fair and poor condition

The use of low quality livestock overstocking or other poor management practices can easily offset the advantages arising from excellent to good condition range Actually, returns may be greater from fair-condition range than from good condition range Management practices on fair condition ranges usually are in keeping with the condition of the forage These factors on a good condition range are given little or no attention However when good management is practiced returns are usually greater from excellent condition than from lower condition ranges

MEANING OF GRAZING CAPACITY

Forage production in the western United States varies annually because of weather On perennial ranges production may vary threefold Production of annual vegetation may vary tenfold from one year to another Such variation requires either very conservative use in productive years a flexibility in number of livestock from year to year

Proper stocking is regarded as the largest cattle or sheep numbers that can graze each year on a given area of range They may graze a specific number of days without causing a downward trend in forage production, forage quality, or soil

In many ways, this is a wasteful method of determining rate of stocking If forage is to be adequate in years of low production, there must be excessive amounts of unglazed forage in years of high production We have no reason to believe overuse in one year can be made up by underuse in another year Hence, stocking that results in correct use in the average year does not appear to be the answer The general practice is to stock so as to prevent overuse of available forage in any but the most extreme drought Stocking

should be heavy enough at all times to adequately utilize the forage.

In determining the stocking rate, it should be emphasized that some plants must remain on arid ranges when the range is fully used. This is absolutely necessary to plant welfare. Rainfall is not sufficient always to give enough regrowth of foliage to replenish food reserves. Grazing capacity is also influenced by the lack of uniform distribution of livestock. Cattle, especially, are not uniformly distributed over a range of steep topography. More accessible spots may be grazed to a dangerous degree before full use is made of less accessible forage. Rate of stocking must be based on the capacity of important accessible spots or "key areas" rather than on the forage produced over the entire range.

RANGE CONDITION

Range condition descriptions date back to Biblical times. Early herdsmen associated condition chiefly with weather. In fact, effect of weather is so direct and obvious that other factors are frequently overlooked and even denied. Range students have recognized that long droughts cause changes. There are changes, not only in the amount, but also in the botanical composition of the plant cover. They have also known that ranges run down from misuse of plants and soils through both wet and dry years.

Stockmen have been slow to accept such evidence as a reason for adjustments in grazing. Long experience has shown a constant and direct relation between weather, forage, and returns. Furthermore, with the same weather, differences in productivity were charged to different kinds of rangeland rather than to conditions on the same kind of land. Acceptable evidence of improvement or decline, therefore, requires separating the effects of grazing from the effects of weather. It is also necessary to show the effects of different grazing practices on the vegetation of different kinds of land

DEVELOPMENT OF AN APPROACH

The effect of grazing on the condition of two kinds of ranges were studied over a nine-year period in the Southwest by the Soil Conservation Service. One range was a natural prairie on clay soils. The other was a savannah grassland containing scattered trees and drought-resistant undergrowth on sandy soils. In each, comparable

soils and climate made possible comparisons of undisturbed areas with areas having various grazing histories.

The results permitted measurements of the degree of departure from climax. These results were used in the development of a suitable range inventory. This approach was based on research findings and on testing these findings over a wide range of conditions.

Several methods of rating range condition have been and are being used by various agencies. However, this qualitative-ecologic approach is used by the Soil Conservation Service in assisting ranchers to establish soil and water conservation programs.

DEFINITIONS AND APPLICABILITY

The term "rangeland" is applied to grassland areas. These areas have soil and climatic conditions which, through secondary plant succession, lead to climax suitable for natural pasture. Thus, areas with prairie, savannah, or desert-shrub climax are included while areas with forest climax are excluded.

The term "climax" refers to a relatively stable vegetation where plant succession is equal to soil development. It is believed that classification of range conditions should be limited to ranges or natural pastures. They should not be applied to tame pastures unless the object is to restore such areas to natural pasture.

Natural plant succession operates to improve ranges. But on tame pastures the same process operates to replace the artificially established vegetation with natural vegetation. When there is not an adequate natural source of seed of successively higher species, seeding may be necessary even on natural pastures.

Wooded lands with forest climax should not be classified as range. They should be classified as forests.

The term "condition" is used here as a "state of being." Because conditions may be changing, a report of condition always refers to a certain time. A practical classification of range condition must provide sufficient freedom within each class. Enough freedom permits inventory and mapping of range to potential condition. This enables a range manager to recognize an attainable goal.

Condition ratings are sometimes improperly applied to the "forage types." Forage types themselves frequently represent a condition. The need for distinction between site and forage type is necessary. Range condition should express departure from potential.

Consequently, description of sites must precede efforts to determine condition.

A distinction must be made between condition and trend. "Trend" is used in the common sense: that is, "a general course or direction." Ecologically, upward trend is secondary succession. Downward trend is degeneration of the vegetation. Current trend must be known in order to adjust management intelligently. Thus, a change in trend due to seasonal drought may require immediate but temporary reduction in livestock numbers.

Soil erosion and soil stabilization are generally associated with range condition. Both should be regarded, however, as features of trend rather than condition. For example, during an erosive summer rainstorm, some soil and even plants might be lost. After the storm, established plants might send out enough new shoots to re-establish the soil. The net change in soil or vegetation a few months after the storm might be too small to measure. It would not provide a basis for change in management. Nor would a new range condition class be recognized. This is true even though minor changes in condition would have occurred.

At the other extreme, a summer storm might erode virtually all of the soil from a poorly managed mountain slope. In that case even the basis for classifying the condition of the site would have changed. Before the storm a cover of perennial midgrasses may have been the climax. After the storm, the area might support little more than scattered annuals. The presence of the annuals would represent excellent condition. Evidence of past erosion is evidence of past site modification. Range condition should be rated with respect to the greatest amount of vegetation the site can produce at the time of rating.

Removal of livestock during the growing season should result in an upward trend. Grazing of a pasture in alternate years causes alternating upward and downward trends in the vegetation. But it is not wise to change the condition class each year.

PRINCIPLES AND PRACTICES

Under climax or original conditions, close relations existed between kinds of vegetation and kinds of soil in each climate. Now, the vegetation on most ranges also reflects grazing use. Under grazing, the vegetation deteriorates much more rapidly than the soil. It

is thus possible to determine the potential composition and forage production of grazed sites. This is done by comparing the depth of topsoil of grazed areas with that of areas in the same climate that retain climax or undisturbed vegetation. Normally soil and vegetation develop equally up to a point. This point is limited by climate.

The interaction of soil and vegetation in normal development may be alternated by grazing. The result is a "kind of vegetation" not in balance with soil. The extent of this departure determines range condition. Natural processes operate constantly to restore equilibrium. Consequently, natural processes alone will in time restore the range to top condition if permitted to operate.

Prairie species have been divided into three groups: "decreasers," "increasers," and "invaders." The proportions of these groups present provide a quantitative index of range condition.

The decreasers and increasers are species found in the climax plant communities. Decreasers are those which, under grazing use, decrease from the percentage found in the climax. Increasers are characterized by a period of increase, after which they too may decrease Invaders are species that enter plant communities as the climax vegetation is destroyed. Invaders cannot withstand the competition of the climax community. If invaders were present in the original vegetation, they occupied disturbed areas (such as mounds of burrowing animals).

Trends in relative amounts of the three groups of plants were used to develop a method showing the course of degeneration. Hence, the nature of secondary succession to be expected on specific sites was shown.

The course of degeneration may be finely divided into four condition classes: excellent, fair, good and poor. The total of decreasers, increasers, and invaders is always 100 per cent.

In using this system, field men make a preliminary study of pastures. They determine the climax species. They also use available local research information. For each site they prepare lists of decreasers and invaders. The increasers are listed with their known maximum relative coverage in the climax for each site. This provides data for application of the method.

It has been found practical to estimate relative coverage of decreasers, increasers, and invaders to the nearest 5 per cent. This is based on the total of all foliage produced in average years. Relative amounts of various species are more certain evidence of position

than is the density of total vegetation. Annuals and treetops beyond the reach of livestock in savannahs must be included in the estimates of the relative amounts of decreasers, increasers, and invaders. Increase or invasion by annuals and woody plants results from range destruction.

To check forage production on a range in each condition class, a two-foot square can be laid out. The vegetation inside the square is clipped and weighed. Litter in this same square should be collected and weighed. This shows how much is being returned to the soil. These weights reflect the accumulated amount of litter but not the exact amount returned in any one year.

Grass production can be increased several times by properly managing a range to bring it back to excellent condition.

CORRECT STOCKING OF RANGE IMPORTANT

Correct use of grasslands is the key to maximum sustained livestock production. It is the way to obtain forage growth needed to provide adequate protection for the land from falling raindrops and from wind.

A rancher in Coke County, Texas, produced more pounds of lamb and wool from 200 ewes per section than was previously obtained from pasturing 250 ewes per section on the same land. The 200 ewes, managed under a deferred grazing system in spring and then pastured on a rotation system, produced lambs with an average weight of 71 pounds. This is 24 pounds greater than the average weight (47 pounds) of lambs from ewes grazing at the rate of 250 per section.

On a sheep and cattle ranch near Presidio, Texas, heavy stocking with lightweight ewes resulted in a low lamb crop. This lowered the total production of livestock products. The rancher reduced the number of animals by approximately 30 per cent. He obtained higher yields, increased lamb crops (90 per cent compared with 65 per cent) and higher calf crops. Dividing large pastures into several smaller pastures permits correct seasonal use. This is one of the important ways of maintaining range in good to excellent condition.

The proportion of annual growth of forage that is harvested by livestock is an important factor in maintaining plant vigor. Plants must have adequate leaf surface and rest periods to stay strong and vigorous. Vigorous growth of palatable plants is assurance that livestock receive nutrients essential to greatest growth.

Destruction of too much top growth by excessive grazing is the first step in range deterioration. The process is sped up by other developments. These developments make it difficult for better forage plants to survive. Invasion by less desirable plants indicates range decadence. Management practices that permit desirable plants to grow normally are essential to restoration and maintenance of desirable species. Highest sustained production of livestock results.

SEASON OF USE OF FORAGE IMPORTANT

The season of use is important. It may influence range maintenance as much as intensity of grazing. The danger of grazing too early in spring is well known. Amount of use in the fall may be equally important. It is generally thought that perennial grasses are immune to damage during their period of dormancy. Studies show, however, that growth is in process throughout the year. Damage may be as extensive during the so-called dormant stage as during the early stages of seasonal growth.

Fall grazing of blue grama may be a more critical period than spring. This is due to the fact that the roots and buds are getting set for growth during the next season. Since this is true, deferment of fall grazing assumes great importance in managing range land. Seedlings of blue grama rarely develop into plants. New shoots are readily developed and management should encourage this process.

Ranges in fair or poor condition need longer rest periods than those in good or excellent condition. Rest periods restore the productive capacity of the desired forage species. Even moderate grazing should be postponed at times. It should be delayed through the growing season and in the fall. It should be delayed until danger of disrupting the normal growth processes is at a minimum.

ADJUST GRAZING LOAD TO FLUCTUATION IN FORAGE PRODUCTION

Variable factors make the adjustment of current grazing use difficult to coincide with annual fluctuations in forage production. A system offering a practical solution to this problem is being used by a number of ranchers. During a low rainfall year, this system adjusts size of breeding herd to the anticipated forage production. It also adjusts to other factors contributing to below-average production. During years of surplus forage production, calves may be carried

over to utilize the forage. Marketing dry cattle and culling inferior stock is the first step.

Experiences during the recent drought in the Southwest range country have shown the soundness of such a program. Ranchmen brought their herds and grass through Texas' greatest drought in an almost miraculous manner. Table 28 gives the livestock production record of the 10,000-acre ranch owned and managed by Edwin Sawyer, Sonora, Texas.

TABLE 28

LIVESTOCK PRODUCTION, EDWIN SAWYER RANCH, SONORA, TEXAS, 1948–1953

Rainfall	*Number of Sheep*	*Lamb Crop*	*Total Lamb*	*Total Average Weight of Lambs*	*Date Sold*	*Total Pounds of Wool*	*Cattle*	*Calf Crop*	*Average Weight of Calves*
(inches)		(per cent)	(pounds)					(per cent)	
23.33	2057	85	57420	58	6-18	16338	92	90	504
36.72	1906	94	67720	62	6-14	15177	104	92	495
13.15	1924	104	86144	66	8-18	13336	91	94	446
8.82	1907	92	65769	61	8-1	15830	97	91	373
10.92	2034	77	65089	65	7-16	16107	98	91	506
6.19*	1647	102	74763	66	7-1	13660	92	88	460

rainfall 6.19 inches late into summer

Sawyer's lamb, wool, and beef production held almost the same from . The last four years were extremely dry. This unusual success is due to the kind of grassland management Sawyer used for several years. Sawyer gave his range good care prior to the drought. As a result, the range kept on producing in the scanty rains that fell during the four severe drought years. Sawyer's grass was hurt during the dry spell, but enough good grass remained on the ground to have regrassed the range had good rains followed.

DEFERRED GRAZING INCREASES FORAGE PRODUCTION

Deferred grazing (delayed use of forage on portions of the range) provides a practicable system of increasing forage production. Buffalo grass yields as much as 20 per cent more forage when grazing is deferred six to eight weeks during the growth period. Additional feed resulting from this practice is important to the production of higher yields.

Buffalo grass and other plants of similar growth habits, like curly

mesquite, respond to short periods of grazing deferment. Blue grama, sideoats, and the bluestems make a greater contribution of forage when deferment is for a longer period.

Tobosa, threeawn, and black grama have peculiarities unlike the plants mentioned previously. These are attractive to livestock for only short periods during the year. In mixtures with more palatable plants, these less preferred plants are not fully utilized. When they occur in appreciable quantities, they may be isolated for use during the brief periods when they are most succulent. Otherwise, plants with higher palatability may be grazed excessively. At the same time less preferred plants are given an opportunity to increase. They then make up a larger part of the plant community.

Knowledge of the kind and amount of forage available is essential to good range management. Knowledge of seasonal development of the forage plants is also important. Time and intensity of the harvest to which the plants can be subjected without reducing the maximum yield of forage for livestock production should be known. These are fundamental. They should be considered in planning the use of range lands. This will make it possible for ranges to yield their highest continued production

MANAGEMENT OF RESEEDED RANGES

Much progress has been made during the last twenty years in seeding perennial grasses and legumes. Grasses are seeded on submarginal and adapted areas of rundown ranges. Unfortunately, young seedlings are often grazed before they are well established. They are also grazed too early in the season as well as too closely and for too long a period. This causes early loss of some good to excellent stands.

Experience shows it pays to protect new seedlings from all grazing until the young plants develop good roots. Roots which can anchor themselves to withstand the pulling effects of grazing are developed one to two years after seeding.

Seeded grasses are just about as delicate as the important native perennial bunchgrasses. Neither will hold up very long under excessive use if grazing begins early and continues throughout the spring and early summer. New growth of the more palatable grasses, if closely grazed in early spring, will be repeatedly grazed throughout the growing season. This prevents the storage of needed food

reserves in the roots. It exhausts the stored food and results in early starvation and death of the plants.

Three management practices apply equally to seeded and native perennial bunchgrass range. They also make up the range improvement program. These three groups are: grass or forage management practices, facilitating or enabling practices, and special forage improvement practices.

GRASS OR FORAGE MANAGEMENT PRACTICES

Grass and forage management practices must be used on both seeded and native perennial grass ranges. They are particularly necessary if yields are to be maintained. These practices include rotation and deferred grazing, proper use of grasses, and fire prevention and control.

Rotation and deferred grazing are the most important management practices. If properly used, they allow the livestock to harvest each year's forage crop. The crop is harvested with the least disturb

Figure 18-4. Excellent condition range in Clay County, Texas. This luxuriant plant cover, principally high producing bunchgrasses, provides effective erosion control and furnishes a maximum amount of feed. (Soil Conservation Service Photo)

ance of normal plant growth. It is possible for plants to store up needed food reserves in their roots each year. This is necessary for survival during the dormant season. It also permits good growth the following winter or spring by enabling the important grasses to produce seed.

Rotation and deferred grazing on ranges work most effectively on three, four, five, or six pastures of equal forage production capacity. This is true regardless of whether grazing is during spring and fall or during the spring, summer, and fall. Two-pasture systems work quite effectively on summer ranges.

Proper utilization of seeded and native perennial forage grasses safeguards their vigor. It assures maximum production and lessens hazards imposed by steep slopes and unstable soils. Proper utilization permits accumulation of residues. This protects the soil from splash erosion and increases water intake. This increased supply of water assures higher forage production. Benefits resulting from continued proper utilization of forage grasses are cumulative. That is, they improve with time.

Fires can undo all gains made from reseeding, rotation, deferred grazing, and proper utilization.

FACILITATING OR ENABLING PRACTICES

The installation of certain facilitating and enabling practices is essential. They are necessary for successful forage management programs. These include adequate water supply, fencing, and proper placing of salt.

An ample, clean, dependable supply of stock water is important in grass management. The water should be well located in each seeded and native pasture. It should be ample to water herds daily during each grazing period. A poor water supply in any one pasture prevents the use of an effective rotation-deferred system of grazing. Springs, ponds, and wells may be used to supply water.

Planned fencing, especially on cattle ranches, is the key to the control of livestock numbers on any pasture. Periods and degree of grazing in each rotation and deferred pasture should be governed by the condition of forage.

New seedlings must be protected from grazing until they are well established. On cattle ranches, protection usually requires the construction of either temporary or permanent fences. Permanent

fences are expensive. They should be built only on pasture boundaries designed to fit into a long-time rotation and deferred grazing system. New seedlings on part of a pasture may be protected by temporary fences.

On sheep ranches, new seedlings can be protected by herding flocks of sheep away from seeded areas. An effective rotation and deferred system of grazing can frequently be carried out on sheep ranches without fences. This is especially true on ranges divided into natural grazing units by such topographic barriers as streams and prominent ridges.

The well-known practice of placing salt away from water should be applied to new seedlings. The salt should be placed in the least-used parts of the range.

Building up and using enough winter feed reserves makes it possible to delay grazing of the reseeded areas each year until they are ready for grazing. This keeps stock off the range for about twenty-five days in early spring. Extra fall feed for about twenty days assists also. It makes it possible to remove the stock from seedlings in the event that early rains make the ground too unstable for grazing.

SPECIAL FORAGE IMPROVEMENT PRACTICES

Brush eradication and control, range fertilization (especially of annual crops), and reseeding are three special forage improvement practices which are important.

A number of varieties of brush invade new seedings and old stands, even under light grazing. Thus far, mechanical means of control have not generally proved practical. Some of the chemicals now in use offer more promise.

Successful stands of perennial grass and legumes in central and southern California have been established. Good cultural practices have made this possible. This included the use of fertilizers after a year's establishment. Fertilization of native perennial grasses is as yet a relatively new field but promises to become more important.

Good production management begins before seedings are made. The best sites should be selected for the first seedings. An existing pasture with deep, fetrile soils but in a rundown condition is a good seeding site. Sites that can be developed into new and practical pastures may be seeded also. Seeding of abandoned croplands has

proved satisfactory in many instances. Their soils usually are deeper than the average range soils and the chances for success are good. Seeding areas should be large enough to justify establishing facilities for proper grass management

Where new seedings are mixed with native range, they should be extensive enough for an economical unit This encourages the rancher to protect them in his grazing management program.

The degree of grazing use of seeded and native forage species varies from 30 to 70 per cent The safe degree of use depends on a number of factors. They include important grass species, stability of the soil, slopes, periods of grazing, and other factors affecting safe use of forage

EVALUATING RANGE FORAGE

More net profit can be made from conservative grazing than from overgrazing Keeping grazing use in line with grass yield produces

Figure 18 5 Good condition range in Nebraska A plant cover such as this in which perennial bunchgrasses still predominate, is effective in reducing raindrop splash erosion Range of this sort produces from 75 to 90 per cent of all the forage possible (Soil Conservation Service Photo)

more pounds of animal products from fewer animals than when the range is overstocked. As a result of this discovery, the Soil Conservation Service developed a method for determining the grazing capacity of range land. It is known as the "range-condition method." Under this method, the range is classified as to condition by ecological types.

Each major plant association generally represents an ecological climax. But all areas within the climax may not have the same production possibilities. The classification is designed to indicate the relative productivity of different range areas. Consequently, types differing in potential productivity must be separately described.

The value of range lands commonly varies in proportion to the amount of forage produced. This forage production can be expressed as range condition. In general, the higher the forage production, the better the range condition.

Such factors as forage composition, erosion, litter accumulation, and forage density differ in the several condition classes. Range condition is determined by analyzing and segregating these factors. A scoresheet or guide has been developed for the rapid classification of all the ranges of this type.

Excellent-condition ranges. Ranges in excellent condition do not need restoration. They already are producing all the forage possible under the existing climate. The plant cover protects the soil from abnormal erosion and maintains the fertility. The better forage plants particularly the deeper-rooted perennial grasses - predominate. However, there are some palatable weeds and shrubs on some ranges. Better plants reproduce well in favorable years Some litter covers the ground. The topsoil is loose and friable, containing dark organic matter. There is more organic matter in areas of high rainfall than in the semi-desert. The soil is porous and readily absorbs large amounts of moisture. Runoff water is clear. Ranges in excellent condition serve every purpose as fully as possible.

Good-condition ranges. Ranges in good condition generally are satisfactory, although they produce less forage than those in excellent condition. The better perennial plants predominate but there are some less palatable ones. The plant cover is thinner. Usually there is less litter and the topsoil may contain less organic matter. Erosion, if it occurs at all, is slight. Ranges in good condition should be grazed conservatively. They should be managed so as to en-

Figure 18-6. Fair-condition range near Pecos, Texas. (Soil Conservation Service Photo)

courage the more palatable plants. Restoration is not difficult or time consuming The better forage plants and soil are still there for quick improvement

Fair-condition ranges. Ranges in fair condition are unsatisfactory The climax cover has been so severely disturbed that restoration may be a slow process Valuable forage plants are considerably reduced in stand Their place is occupied either by bare soil or less palatable perennial grasses, weeds, and shrubs Annuals have usually increased. There is less total plant cover and litter Without sufficient plant cover (2000 lbs per acre) there is apt to be active erosion, particularly on slopes The dark topsoil layer may be seriously disturbed It may contain only moderate amounts of organic matter and have only fair capacity to absorb and hold moisture The exposed surface of clay and silt soils may be hard and crusted. Runoff water may be loaded with silt Fair ranges slip quickly to a poor condition if neglected but, when handled carefully, they can gradually be restored. Reseeding is often practicable.

Poor-condition ranges. Poor-condition ranges have lost much of

the forage stand. In some cases much of their topsoil has been lost. They produce only a fraction of the forage grown on similar ranges in good or excellent condition. Few of the more valuable perennial forage plants remain. Low value annuals or such perennial weeds and shrubs as snakeweed, juniper, and mesquite may predominate.

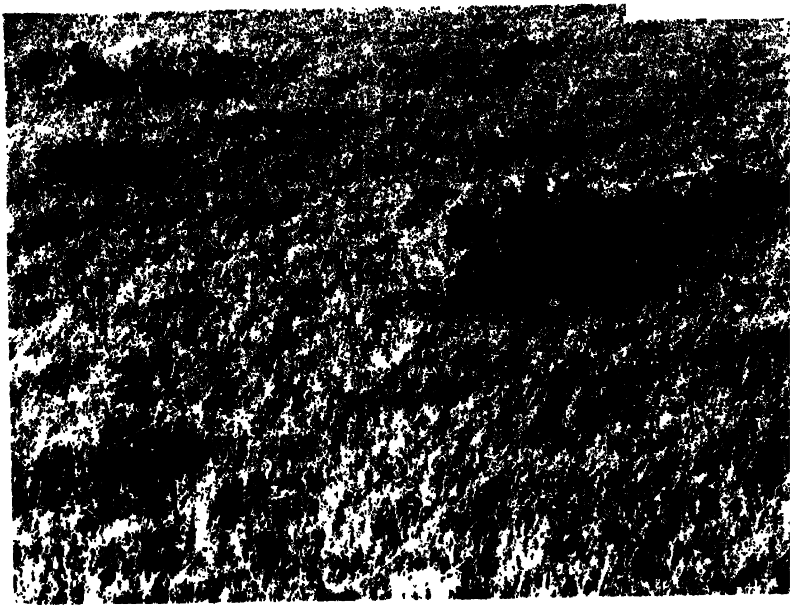


Figure 18-7. Poor-condition range near Nocona, Texas: Just 100 yards away, and on the same site, was a range in excellent condition. The principal plants here are prickly pear and Japanese bromegrass. (Soil Conservation Service Photo)

In extreme cases removal of topsoil by washing or blowing may have exposed the subsoil or left a gravel "pavement." In this case the soil may have little organic matter and a low moisture-holding capacity. There may be active splash- and some gully-erosion. Run-off may be rapid and heavy with silt. The job of restoring poor range to full productivity is a major one. Years, even decades, may be required to gradually build back the organic matter in the topsoil that marks satisfactory condition. Where soil and moisture conditions permit, ranges in poor condition should be reseeded. They should be seeded to adapted forage species to hasten recovery.

Questions

1. What is the main cause of erosion on our range lands?
2. What do we mean by "range condition"? How many range condition classes are there?
3. Describe each of the range condition classes.
4. How much range forage per acre is necessary to protect the ground from water erosion? What is the best way to determine the effectiveness of range forage against water erosion?
5. How does range forage protect the soil from water? Wind?
6. What do we mean by grazing capacity? How is it determined?
7. Why is correct stocking so important in range management?
8. How does deferred grazing increase range forage production?
9. How should reseeded ranges be managed?

19

Woodland Farming

FARM woodland programs are growing in importance for two reasons. One is the increased demand for wood products. The other is the pressing need to find profitable use for much of our severely eroded and abandoned land. These growing needs have stimulated interest in determining the factors most influential in the production of trees.

We have found that an ample supply of moisture is a major requirement for profitable tree production. Furthermore, we know adequate moisture supplies are associated with three specific characteristics of the soil. These are the depth and texture of the topsoil, or A horizon, and the water-holding capacity of the subsoil, or B horizon.

The depth of topsoil determines to a large extent the area for root development. Texture of topsoil and water-holding capacity of the subsoil determines the amount of moisture a soil can hold available for tree production. These factors, when considered together, determine the suitability of a given soil to the growth of trees. We refer to this as site quality. Site quality or site index means height of growth at maturity. If a site has quality or index of 90, it means it will grows trees that will be ninety feet high at maturity. Soils of similar profile, texture, and depth have the same site quality.

Where soil moisture is free of the influence of the water table, stand composition is related to soil texture. In general, sandy soils support pine; loamy soils support hardwoods; and clayey soils support both conifers and hardwoods.

Figure 19-1 Excellent stand of mixed hardwoods (oaks, poplar and hickory) in Arundel County, Maryland. Trees range from twelve to thirty inches in diameter. Most of the trees are straight and more than 100 feet high. They have a good underbrush cover with heavy leaf mold. (Soil Conservation Service Photo)

SITE QUALITY

Knowledge of site quality is important to proper management of woodland. This is true for both the establishment of new stands and the most economical management of established stands. It also enables the operator to determine where tree planting and other intensive management will be desirable and practical. Knowledge of site quality is especially needed for denuded lands and lands that may have agricultural value. With this knowledge a farmer can determine the best use of the land. Knowledge of the site quality of established stands enables the manager to estimate wood products he can harvest during a specific period of growth. He can estimate with a fair degree of accuracy the volume of wood products he may expect to harvest.

Several investigators have tried to develop a method for determining site quality. Some succeeded in developing one that is appli-

cable only to established stands of a particular species. Moreover, they apply only to that species when its growing conditions are similar to those under which the methods were developed and they can be used only by one trained in forestry. What is needed is a method of site quality determination applicable to any site. It should be applicable whether trees are present or not. It should be simple enough to be used by a person with little or no forestry training.

SOIL PROPERTIES AND SITE INDEX

Numerous studies have been made of the relationship between various soil properties and the rate of growth of forest stands. The soil properties are the same as profile characteristics. Growth rate is determined by site quality. In the United States most of these studies were made east of the Great Plains region.

Northeast. A study was made in Connecticut to determine the relation between the site index of young red pine plantations and the silt and clay content of the various soil horizons. The site index of red pine increased as the percentage of the silt and clay increased in the A horizon—topsoil. Red pine had a higher site index on sandy loam and loam soils than on loamy sand or sands. This condition is also true in the Lake States region. In the Lake States, jack pine does better on coarser soil than either red pine or white pine.

Another study in Connecticut showed little relation between site index and individual soil characteristics. By this, we mean such characteristics as soil series, texture, and the subsoil. No relation was found between the acidity of any soil horizon and the site index of red pine. Silt plus the clay content of the A horizon showed a fairly good relation with the site index. Site quality improved as the combined silt and clay content of the soil increased up to 25 per cent. This was in line with the findings of the earlier study in Connecticut.

Total nitrogen content of the A horizon showed a better relation to the site index than did any other factor. Total nitrogen content of the surface soil was assisted by other factors of the soil site and vegetation complex. For example, soil nitrogen should increase with increasingly favorable moisture conditions. Improved moisture conditions increased the growth of vegetation. Increased vegetation produced more organic matter, and as the organic matter increased the physical condition of the soil improved.

It is believed that the lack of stronger relations between the site

index of red pine and the soil characteristics in Connecticut was due to the age of the plantations. The trees were under thirty years of age. It is thought that the subsoil characteristics, the parent material, and the moisture conditions, as influenced by topography, are more effective on older trees. As trees grow older, they compete more for growing space. Competition for growing space, moisture, and nutrients becomes acute in forest stands older than twenty or thirty years. Unless forest stands are greatly overstocked when they start, they do not develop a conspicuous concentration of small roots near the surface until they are twenty to twenty-five years old. When this concentration of surface roots occurs, competition for moisture and nutrients during the growing season may occur. Surface roots can be called a forest soil *root profile*. At this age, trees must depend partly on roots at lower depths in the soil and substratum for the absorption of water. Where subsoil characteristics or the relative topographic position is unfavorable for root growth, tree growth is reduced when roots in the surface soil zone compete strongly for growth materials.

Other studies in Connecticut show that both the frequency and total numbers of plants were higher on moist soils than on drier soils. This study did not show any plants that were good indicators of soil types.

A survey of the composition and stocking of cutover old-field white-pine lands in central New England showed that very light soils should be planted to pine or allowed to grow hardwoods for cordwood. This survey showed that better sites should be used for hardwoods for sawlogs.

Studies were made in the Adirondack region of New York to determine the effect of soil on tree growth. Stand tables were made and height and radial growth data were collected on four one-acre plots in each of four forest types. These types were northern hardwood, spruce hardwood, spruce flat, and spruce swamp. One soil well ten feet long was dug to a depth of root penetrations (three to five feet) in each of the sixteen plots. These wells provided information on profile characteristics, on the texture of the various horizons, on *p*H, and on the amount of stone in the soil.

No difference was found in the mechanical composition of the mineral soil horizons in the various types. The hardwood forest types were on Essex sandy loam. The spruce hardwood and spruce flat forest types were on Beckett sandy loam. The spruce swamp

soil was peat over sand. The total height of dominant and codominant trees (uneven-aged stands) was arranged in the forest types in the following order of decreasing productivity: hardwoods, spruce hardwood, spruce flat, and spruce swamp.

Marked response in the growth of red pine and white pine to surface applications of organic matter was found on infertile deep sands in the Adirondacks of New York. The organic matter increased the soil's water-holding capacity. It also supplied some significant fertility factor. The response was evident the first year after the application of green slash. The height growth of commonly planted forest trees in New York State is greater on peat than on muck. This relationship is due to the fact that the favorable soil site factors conducive to peat formation are related to rapid tree growth. These factors include good physical soil properties and favorable moisture and aeration. Of course, extremely sterile sands may also be deficient in mineral nutrients.

The productivity of the wind-blown sandy soils in parts of the Northeast is extremely low. These soils are comparable in some respects to the sandhills of the Southeast and the deep sands of Michigan. In the Northeast, when such soils were cleared, wind erosion frequently developed. Their suitability for forest plantations was further reduced because of the loss of organic matter. Mulches of organic matter like manure, straw, hay, weeds, or tree slash increased both survival and growth of conifers on these wind-blown sands in Vermont.

Studies were made of the relationships between soil types and forest site quality in the northeastern Appalachian plateau of east-central and south-central New York. The soils of the region are derived from glacial deposits. They are genetically young and strongly influenced by the nature of the parent material. The parent material may be acid or alkaline.

Sugar maple and beech were found throughout the area, along with other species. On the basis of types of humus layers and occurrence of wind throw, deep, well-drained soils with an alkaline influence in the subsoil were found best for the natural hardwood forests. On the other hand, shallow soils and those with poor internal drainage were of low quality for the local hardwoods. Poor internal drainage was related to failures or to poor growth in coniferous plantations.

Studies were made of the relationship of depth to water table in

various soils in south-central New York as it was influenced by kinds of soil. The study showed that the occurrence of roots was markedly affected by the presence of a water table in the poorly drained soils. However, the few data obtained on heights of trees showed no apparent relation to the presence of high-water tables. On the basis of soil conditions in that area it appears that adequate data would have shown the expected relations between poor sub soil drainage and stand composition and site quality.

Lake States. The Upper Peninsula Experimental Forest in Michi gan was subdivided on the basis of soils and vegetation. A study of this arrangement showed that the classification of forest tracts on the basis of cover types for management purposes may not be entirely satisfactory. Cover types often represent a temporary condition. Thus they do not give a true expression of forest productivity.

It was thought that analysis of the soil might show a broad relation of soil and forest growth, and it was suggested that this analysis be limited to the following: (1) consideration of topographic features and state of the underground water, (2) study of soil texture and structure, and (3) study of geological and genetic peculiarities of the soil profile.

Forest soils as related to underground water were grouped in three principal types. They were (a) soils in which roots of the plants are permanently under influence of the water table; (b) soils in which the roots are periodically under the influence of the water table, either directly or by means of capillarity; and (c) soils in which root penetration is entirely above the water table.

The limiting factor of swamp forest growth, under (a) above, is the degree of water stagnation. In the Lake States, fibrous peat produces no forest growth but sedges. Sphagum peat supports water-loving stands of black spruce and tamarack. Fine woody peat supports such water-loving hardwoods as black ash, red maple, yellow birch, willow, and numerous shrubs. Coarse, woody peat is associated with white cedar. The typical vegetation of muck is alder.

Swampy soils, developed under the partial influence of the water table, support stands of pine if they are coarse textured However, if they are finer textured the forest stand includes such hardwoods as ash, elm, red maple, sugar maple, and yellow birch. They also include mixtures of conifers like white pine, hemlock, spruce, and balsam.

If the soil is above the influence of the water table, stand compo-

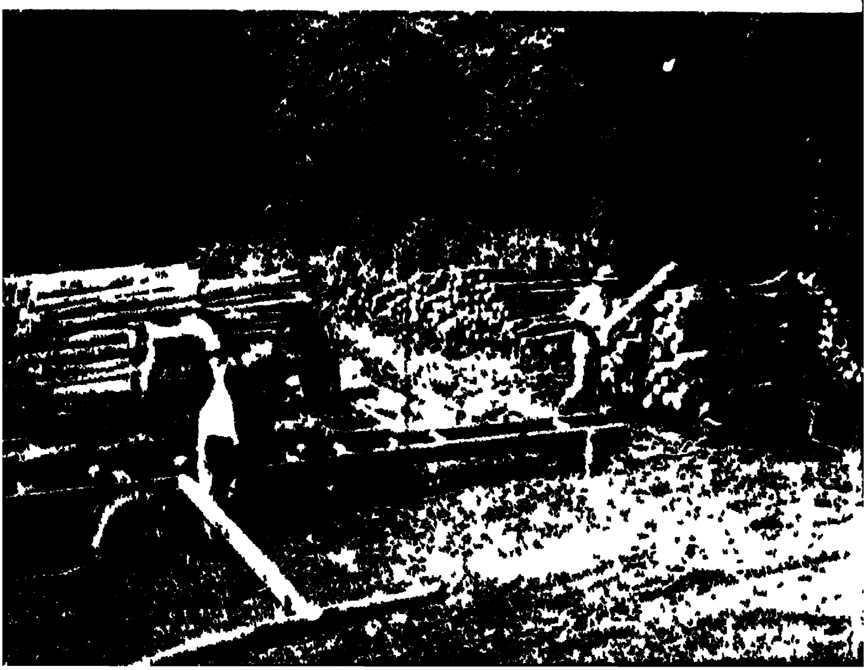
sition is primarily related to the texture In a few cases, it may be related to the structure of the mineral soil In general, sandy soils support pine, loamy soils support hardwoods, and clayey soils support both conifers and hardwoods Hardwoods have more exacting site requirements than conifers The poor sites are usually occupied by other forest types

The relation between soil characteristics and site index may be summarized as follows

Soils of Group 1 Loams, sandy loams, and loamy sands with yellow sand substratum fifteen to thirty inches below the surface ordinarily occur as Site Index 80, although locally they may occur as Class 90 Shallow or stony phases of any of these soils may occur as Class 70

Soils of Group 2 Loams and sandy loams with a sandy clay till or drift substratum twenty-five to thirty inches below the surface occur as Site Index 90, except where stony When stony they occur as Class 80 Where shallowness is combined with stoniness they may occur as Class 70

Figure 19-2 Well-managed woodlands supplement the farm income Woodland on this Ohio farm supplies mine props, sawlogs, and cordwood (Soil Conservation Service Photo)



Soils in Group 3. Silt loams and loams with clayey or sandy subsoils occur as Site Index 90, except in the case of very stony soils.

Soils in Group 4. Silt loams and loam with open coarse sand, gravel, and cobbles below forty inches occur as Site Index 90, except in cases of shallow or stony soils.

Soils in Group 5. Shallow soils resting on bedrock occur as Site Index 80.

Pine soils of northern Michigan have been grouped into three classes. Regular soil types important in the area were ranked as follows:

1. *First-class pineland.*

   Ogenaw sandy loam: low lying, smooth, moist, sandy-loam surface soil underlain at 2.4 feet with red clay.

   Roselawn sandy loam: sandy moranic (lake) deposits, strata of sandy clay or clayey sand in B horizon and in the parent material.

2. *Second-class pineland.*

   Roselawn sand: coarse-textured surface and few clayey strata.

   Rubicon sand: flat, well-drained, with yellow B horizon six to twelve inches from surface.

   Bridgman fine sand: wind-blown deposits, fine sand

3. *Third-class pineland.*

   Saugatuck sand: hardpan five to twelve inches from surface averaging eighteen inches thick.

   Wallace fine sand: wind-blown, hardpan.

   Grayling sand: practically no fine sands, silt, or clay, low water table. This is one of the first soil types to be planted to crops because of the ease in planting and it is the first to revert to the state for taxes.

A study of interrelationships of soil and the site index of aspen was made in Minnesota and Wisconsin. The relation between the site index of aspen and the following factors was studied: soil texture groups, geological formation groups, combined texture and geological formation groups, soil profile groups, and natural community plant indicator groups. The site index of aspen was found to be most closely related to soil profile groups, to natural community plant indicator groups, and to combinations of the two.

The site index of aspen is a more reliable measure than volume growth. It may be used for the evaluation of the differences and

relative productivity of the aspen habitats. On the other hand, the habitat groups may be established most effectively on the basis of soil profile. These may be used within limits for the production of the average growth of aspen.

The site index of Douglas fir increased with the change in texture from coarse to light to medium. There was no significant difference in the site index of medium-textured soils of different profile groups. Depth of soil was an important factor for those soils underlain by hardpan or by bedrock.

Site index on the same soil profile and texture group was related to mean annual rainfall. Site index of soils increased with increasing rainfall up to forty inches. Above this amount of rainfall, site index decreased for coarse-, fine-, and medium-textured soils. Site index on soils underlain by an impeding layer increased with precipitation up to sixty inches. The greatest increase was up to forty inches. Above this amount the change in site index was small.

Central States. Depth of soil horizons and their permeability, slope, and exposure were important in determining the rate of growth under various conditions of stocking in the Upper Mississippi Valley.

The physical properties of the subsoil were most influential in determining site index, with black walnut and black locust. Plasticity, compactness, and structure of the subsoil showed the closest relation to site index. Both species appeared to act similarly and unfavorably to not enough or too much drainage. Generally, both species made their best growth on such medium-textured soil grades as sandy loams and silt loams.

Yellow poplar makes its best growth on deep, medium-textured, well-drained soils. It will not grow successfully on sites whose original A_1 horizon is less than one inch deep. Yellow poplar will become established and grow rapidly under some conditions. It will grow in old-field covers whose soil has no A_1 horizon if the soil has good physical properties and is well drained. If a soil produces a luxuriant growth of yellow poplar, it will have a large annual fall of litter. This litter is high in calcium and mixes with the soil to eventually form a deep A_1 horizon.

South and Southeast. In North Carolina the site index of shortleaf pine was related to the texture-depth index of the soil profile. The texture-depth index is the ratio of the silt-plus-clay content of the B horizon to the thickness in inches of the A horizon. Texture-

depth indices less than 2 or greater than 8 indicated poor sites. Highest site indices were found where the texture-depth index of the soil was between 4 and 6.

On the average this represents a soil with twelve inches of A horizon and a B horizon containing 60 per cent silt and clay. On such soils, shortleaf pine usually had a site index of 80 feet.

Should the same kind of subsoil be covered with only four inches of A horizon, the texture-depth index would be 15 and the site index relatively low. Development of the texture-depth index was based on the belief that site quality was a function of the amount and favorableness of growth space for tree roots.

The depth of the surface soil and certain physical properties of the subsoil determine the value and quality of growing space for tree roots. This is especially true of soils having a highly irregular profile with respect to texture, structure, and consistence.

Subsoils of the same textural class may have different internal drainage, aeration, consistence, and structural characteristics. All of these factors affect root growth. Consequently, texture of the subsoil alone or in conjunction with the depth of the surface soil is not closely related to site quality for a wide variety of soils.

The height growth of young black locust plantations in Mississippi was related to the depth of the surface soil. Average annual height growth was greater as the depth of the surface soil increased. Depth of soil was the principal factor affecting the growth and character of natural stands of eastern red cedar in the Ozarks. The sites varied from deep alluvial to shallow upland soils less than twelve inches in depth.

A close relation exists between the site index of pine stand in the Piedmont region and the depth of the surface soil and the water storage capacity of the subsoil. These factors determine the amount of water available to grow trees. Deep topsoils hold more water than shallow ones. They also provide more growing space for tree roots. The water storage capacity of the subsoil determines how much additional water the soil can make available to trees. The higher the water storage capacity of the subsoil, the more water the soil can make available for tree growth. A deep topsoil over a high storage capacity subsoil is a good tree-growing soil.

Prairie Plains. In the drier regions of the United States, it has been shown that certain physical soil properties are associated with superior forest sites. These soil properties, which allow rapid infil-

tration, good water storage, and low evaporation loss, are essential. In the Prairie Plains region coarse-textured soils are superior to fine-textured soils for tree growth.

As a result of investigations, there is a growing recognition of the importance of soil tree farming. The soil is an all-important factor in determining the character of the tree stand and its yield in lumber or cordwood. This may seem to be a misstatement, especially when we consider the fact that trees survive in almost any situation where rainfall is ample. This includes our roughest and rockiest land where there is little or no soil.

SURVIVAL NOT ENOUGH

The key word here is survival. There's a vast difference between mere survival and satisfactory growth. Where cordwood, fence-posts, ties, or lumber are to be the fruit of the land, something better is needed—something better than bare rock with a few crevices for root anchorage.

Like any farm crop, trees need moisture and plant food from the soil. And like many crops, forest stands need to be weeded and thinned if growth of crop trees is to be maintained at a maximum.

Unlike most farm crops, tree roots remain in the soil year after year. The rate of demand for plant food during any one season of the year is rather low. Further, the amount of removal from that land is infinitely less. Because of these facts, the rate of natural liberation of available plant food is usually ample in the forest. Fertilizers are not ordinarily needed, even on soils considered to be very poor by farming standards.

However, the more favorable the moisture supply and the higher the rate of plant food liberation, the better the quality of the stand and the more rapid the growth. Both moisture supply and plant food liberation are tied in with properties of the soil.

MOISTURE MOST IMPORTANT

Work at the Connecticut Agricultural Experiment Station has shown that in most instances soil moisture is the most important factor. Moisture relations may be indicated by the soil type. For example, Merrimac loamy sand is a drier soil than Merrimac fine sandy loam or Brookfield loam; and Leicester loam soils are wetter than Gloucester loam.

In some instances moisture conditions vary within a given soil type because of topographic position. For example, trees growing on a sandy soil with a water table averaging five feet deep will grow faster than they would on the same kind of soil with a water table fifteen or twenty feet deep. Likewise, the middle or lower portion of a long slope or the north side of a hill usually has better moisture conditions. Trees on the lower portion or on the north side of a slope are likely to grow faster than those on the upper portion or on the south side.

One of the most striking effects of soil and moisture supply came to light in Connecticut. A five-year-old planting of white pine on Hartford sandy loam was growing 27 per cent faster than an identical planting on Merrimac loamy sand not more than 350 feet away. The increase with Norway spruce was even greater—nearly 90 per cent. Here the difference was not one of soil series as such—Hartford versus Merrimac—but of soil texture and moisture supply. The substratum of the Hartford sandy loam was considerably more moist and tree roots had penetrated to a greater depth than on the block of Merrimac loamy sand.

Studies conducted in Connecticut also showed that the soil in the

Figure 19-3. Much of our eroded farmland should be put in timber. Eroded land on this Maryland farm has been set to red pine. (Soil Conservation Service Photo)

Figure 19-4. The area in the foreground and to the left in this Georgia woodlot is in pasture. The underbrush and litter has been destroyed. A layer of soil several inches in depth has been removed—mostly by splash erosion. (Soil Conservation Service Photo)

woods is decidedly more loose and porous than that in cultivated fields. It contains considerably more organic matter and has a much higher water-holding capacity. Direct comparisons were made in nine separate locations in south central Connecticut. They showed the topsoil in the forest, exclusive of forest litter, contained 48 per cent more nitrogen than the topsoil of cultivated fields. The forest soil was able to hold 40 per cent more water. Further, the forest soils were about 22 per cent lighter. This indicated a better stage of aggregation.

AVAILABLE NUTRIENTS

So far as available nutrients are concerned - especially phosphorus, potassium, and calcium—cultivated soils are usually better stocked. This is because they have been fertilized. But forest soils generally have the advantage over pasture soils. The favorable condition of woodland soils is further enhanced by the litter usually present in undisturbed forests.

RESTORATION OF DEPLETED PROFILE

Cultivation and erosion have changed the surface soil horizon on large acreages of our land. It has been so changed that it has lost

much of its former capacity for absorbing and storing rainfall. This has reduced the water storage capacity and the rate at which water moves through the soil.

Knowledge of the effect of these changes in infiltration and percolation of water is the key to understanding the problems of utilizing these lands. Without this knowledge we can't restore these lands to profitable use. Just as eroded conditions have increased soil destruction, soil rehabilitation must improve water relations. Land use practices that bring about an increase in soil permeability and large pore space offer the only solution to erosion and water problems on these soils.

Forestry practices designed for soil improvement offer the best hope for correcting the errors of past land use on these worn out soils.

CORRELATE SOIL WITH SITE QUALITY

A method was developed for correlating soil characteristics with site quality of Douglas fir in Lewis County, Washington. Soils and other physical features of the land were used in developing the method. The method makes possible the prediction of growth rates, within narrow limits, for this species in that area. It is thought that it may be applicable, with slight modifications, to other areas and species.

The purpose was to correlate soil characteristics with site classes. The results were striking. They were useful for the area and species studied. It is believed that the methods used may be of value to others since they show important relationships between soils and site quality.

The site indices of the stands growing on these soil units showed a remarkably narrow range of values. Site indices on these soils also fall into relatively narrow ranges if northerly slopes are separated.

Ability of the soil to retain and supply water for tree growth in the dry summer period is most important. This ability is determined by texture, profile, depth to porous materials, hardrock, and claypan or hardpan.

FIT THE TREE TO THE SITE

Site evaluation in the selection of tree species for planting is important. This was shown by a study of a large number of field and

gully plantings in the Ohio Valley. Pines and hardwoods were used for erosion control.

In general, pine is least exacting in site requirements. Black locust gives good to excellent results on many sites. Hardwoods other than locust failed in practically all cases as erosion control plantings. Locust grows best on limestone soils. The soils need good drainage, aeration, and moisture-holding capacity. They need to be free from compact impervious layers. Pine, on the other hand, thrives on more acid and less fertile soils than black locust.

Pine is especially superior in old poverty grass sods and on sandy, shallow, and severely eroded sites on residual soils of mixed sandstones and shale origin. These include the Muskingum and Wellston series. Pine is more reliable than locust for field plantings.

Pine is also more reliable than locust on gully bottoms where shale materials predominate. Locust fails where iron or manganese fragments are plentiful. This is true whether it is on gullied or severely eroded areas. Where limestone occurs, giving rise to soils of the Brooks series, locust makes excellent growth. Soils of the Upshur series, derived from heavy nonacid shale, are generally good locust sites.

Locust gives excellent results on well-drained soils of loessial origin. Soils such as those of the Princeton and Memphis series are good. Locust does well in gullied areas of Alford and Grenada soils. Pine does well on loessial soils, especially for field plantings.

Soils of cherty limestone or of coastal plain origin are poor locust sites. Included are those of the Frederick, Bedford, Lawrence, Baxter, Dickson, Brandon, Ruston and Atwater series. Success may be had with locust on the better drained cherty limestone soils if the site is mulched and fertilized. However, pine is more reliable on these soils and is benefited even more than locust by mulching. Of the coastal plain soils, those of the Atwood series are excellent pine sites. Field plantings of pine also grow well on Brandon and Ruston soils, but plantings on badly gullied areas of these soils usually give poor results.

Two-needle pines are less exacting in site requirements than other species. In Ohio and Indiana, red and Scotch pines are best adapted to the poorer areas. White pine gave good results on better pine sites. In Kentucky and Tennessee, loblolly and shortleaf did best on the better pine sites. Virginia and pitch pine were best for the poorer sites.

PREPARE SITE BEFORE PLANTING

Studies were made of numerous plantings of hardwood species. They were used for shelterbelts, woodlots, erosion control, and in reforestation projects. The study showed that planting without some attempt at site preparation was often disappointing. This was especially true unless soil and climatic conditions were extremely favorable. It was also true on severely eroded soil. Examples were found of plantings in gullies and on badly eroded slopes. These showed a low rate of survival, poor establishment of those surviving, and little growth of the occasional seemingly favored tree.

Several hardwood species planted in contour furrows on a 20 per cent slope did much better than similar species planted on the same slope by use of a scalpel.

The growth response to the modification in site preparation of a 1940 experiment was least in the black locust. However, the growth curves for a three-year period indicated that the rate of growth difference between the two treatments increased from year to year.

In most other hardwood species, this divergence was greater than in black locust. Other site preparation experiments with black locust showed greater rate of growth differences where unfavorable site conditions were improved. Black locusts grow well under moderately favorable conditions. They do not need special preparation on good sites. They did show marked response to preparation on unfavorable sites.

The results of this study were predominantly in favor of contour strip planting over scalpel planting. From these experiments, it was concluded that the improvement in plant growth conditions for most hardwoods was due to two factors: improved soil moisture and aeration. These were obtained by improved soil structure on the plowed plots.

CLAY HILLTOP GROWS TREES PROFITABLY

In Washington, a typical clay hilltop underlain by basalt was planted in the spring of 1937. It was planted to a combination shelterbelt and black locust woodlot. The area occupied by the black locust was $\frac{1}{11}$ acre. The black locust were planted on a 6 by 6-foot spacing.

Because of overcrowding, the black locust planting was thinned

to a 6-foot by 12-foot spacing in 1945. Insofar as possible, small, overtopped, and suppressed trees were removed. However those cut were selected also so as not to reduce the effectiveness of the planting for snowdrift control.

A total of fifty-three trees were removed. Their removal required seven and a half manhours of labor for cutting, trimming, and making fenceposts out of those of suitable size. Ninety-three fenceposts were obtained. Forty-two were three inches and over in diameter at the small end. They were considered first quality posts. Fifty-one were less than three inches in diameter at the small end. They were considered second-class posts. All ninety-three were used in rebuilding a fence. They took the place of cedar posts which would have cost 35 cents each.

The value of the locust posts was set at 35 cents for the first-class and 25 cents for the second-class. This gave a total return of $27.45 for the materials removed by thinning from the hilltop planting. The cost of labor for thinning, trimming, and making posts was figured at $1.00 per hour. This made the total cost 8 cents per post. The remaining planting was more valuable than before thinning. It was more valuable for both wood products and snowdrift control.

At this rate, on a per acre basis, the gross return was $302.50 for the eight-year period. This was equal to $37.81 per acre per year. These figures show that black locust woodlots will yield a profitable return on clay hilltops. These areas are ordinarily farmed at a loss.

INCOME FROM FARM WOODLAND

At present, one hundred million dollars' worth of wood products are sold from farmlands each year. Records on Norris-Doxy farm forestry management projects show how management can increase income from farm woodland. Most farms still sell standing timber, rather than processed products. Very few, even among those that are managing their woodlands properly, cut each year or periodically all the wood that grows. Therefore, average incomes from farm forestry projects indicate what farmers will receive by managing their woodlands as they do their fields. Table 29 shows accomplishments from Norris-Doxy farm forestry projects for the fiscal year 1953.

The Tennessee Department of Conservation estimated the income that could be expected from a one-acre pine plantation where

1,000 seedlings were planted. A survival of 850 trees was expected. An additional 85 trees were expected to be lost by suppression and culling, leaving a net stand of 765 trees at twelve years of age. All prices used represent stumpage value.

	First Thinning at 12 Years		
Total number of trees: 765	Yield: 450 posts at		
Cut: 215 trees	.015	6.45	
			$ 6.45
	Select Thinning at 18 Years		
Total number of trees: 550	Yield: 200 posts at		
Cut: 230 trees	.015	3.00	
	5 cds. pulp at 3.00	15.00	
			18.00
	Third Thinning at 24 Years		
Total number of trees: 320	Yield: 100 posts at		
Cut: 105 trees	.015	1.50	
	8 cds. pulp at 3.00	24.50	
			25.50
	Fourth Cut at 30 Years		
Total number of trees: 215	Yield: 4500 bd. ft.		
Cut: 85 trees	at 15.00	67.50	
	2 cds. pulp at 3.00	6.00	
			73.50
	Fifth Cut at 40 Years		
Total number of trees: 130	Yield: 6400 bd. ft.		
Cut: 50 trees	at 20.00	128.00	
	2 cds. pulp at 3.00	6.00	
			134.00
	Final Harvest at 50 Years		
Cut: 80 trees	Yield: 21,600 bd. ft.		
	at 25.00	540.00	
Total Gross Return			$797.45
Less: Land purchase 15.00 and planting costs 10.00 at 5% interest		$286.69	
Less: Taxes, etc. .25 per year at 5% interest		52.34	
Total Cost			339.03
Net Profit $458.42	Annual Net Profit		$ 9.17

TABLE 29

COOPERATIVE FOREST MANAGEMENT ACCOMPLISHMENTS AND EXPENDITURES,* FISCAL YEAR 1953

State	No. of Projs. (Total)	Accomplishments: Woodland Owners Assisted	Woodland Involved	Products Harvested	Gross Sale Value	Expenditures: Federal	State	Total
		(number)	(acres)	(no. bd. ft.)				
Alabama	9	724	93,305	20,981	$ 604,774	$ 21,240	$ 21,495	$ 42,735
Arkansas	2	111	17,582	673	13,005	3,592	3,592	7,184
California	7	645	132,666	34,346	332,143	8,293	37,759	46,052
Colorado	1	85	6,873	783	8,693	2,123	2,124	4,247
Connecticut	4	586	27,724	2,816	48,752	9,800	17,876	27,676
Delaware	1	6	260	10	200	1,200	1,272	2,472
Florida	12	1,469	748,066	36,451	618,118	22,508	41,759	64,267
Georgia	10	737	191,862	19,565	455,358	21,008	26,269	47,277
Idaho	3	34	7,982	38	1,140	2,500	2,580	5,080
Illinois	12	749	24,300	2,930	95,269	24,065	83,362	107,427
Indiana	9	985	42,203	5,744	186,144	12,552	49,798	62,350
Iowa	4	391	12,500	1,850	58,810	7,491	18,223	25,714
Kentucky	8	334	22,373	3,335	58,047	18,000	19,803	37,803
Louisiana	5	170	16,356	2,342	80,503	13,500	14,846	28,346
Maine	9	1,639	63,241	10,182	207,075	18,200	29,601	47,801
Maryland	10	1,871	34,506	12,561	280,524	18,000	46,070	64,070
Massachusetts	2	413	14,779	4,504	66,932	5,464	7,999	13,463
Michigan	7	755	14,657	8,588	247,776	19,973	42,638	62,611
Minnesota	6	518	15,888	4,304	145,417	9,378	22,725	32,103
Mississippi	5	393	82,720	4,540	93,695	13,783	14,813	28,596
Missouri	12	1,393	182,764	8,582	280,189	27,174	47,959	75,133
New Hampshire	8	1,199	50,703	20,065	417,471	18,350	21,805	40,155
New Jersey	1	538	70,151	5,474	97,133	13,099	34,030	47,129
New York	14	2,993	216,776	31,292	768,017	19,100	99,329	118,429
North Carolina	10	1,079	98,034	27,598	802,094	24,876	38,677	63,553

North Dakota	1	52	4,245	685	42,090	2,810	3,157	5,967
Ohio	12	1,286	49,716	6,394	186,034	12,445	66,794	79,239
Oklahoma	2	104	294	..	..	632	632	1,264
Oregon	4	647	29,732	30,657	746,902	8,478	20,772	29,250
Rhode Island	1	175	16,696	35	219	2,500	3,209	5,709
South Carolina	9	903	101,867	20,521	636,532	18,637	31,145	49,782
Tennessee	6	488	32,771	10,183	328,433	16,250	16,819	33,069
Texas	6	516	46,517	1,209	19,869	11,762	11,762	23,524
Vermont	12	3,002	77,432	26,283	662,916	28,600	54,661	83,261
Virginia	9	1,682	156,824	131,389	3,098,043	29,500	105,218	134,718
Washington	6	672	29,620	16,317	321,229	11,338	13,410	24,748
West Virginia	13	1,654	46,468	6,173	156,608	18,800	34,162	52,962
Wisconsin	10	1,476	47,256	8,019	423,389	23,513	68,018	91,531
Total U. S.	262*	32,474	2,827,709	527,419	12,589,543	540,534	1,176,163	1,716,697
U. S. Summary								
F.Y. 1940	.	.	..	.	..	4,793	8,284	13,077
F.Y. 1941 †	9	165	49,416	2,667	31,483	15,342	17,120	32,462
F.Y. 1942	10	224	92,442	10,076	125,307	18,171	19,579	37,750
F.Y. 1943	75	3,242	359,388	75,600	1,043,878	101,076	111,559	212,635
F.Y. 1944	98	8,842	742,697	323,557	3,962,784	187,316	212,209	399,525
F.Y. 1945	100	8,093	831,347	411,330	4,476,354	199,995	230,865	430,860
F.Y. 1946	156	12,083	1,321,746	452,367	6,092,499	315,441	369,065	684,506
F.Y. 1947	153	13,531	1,576,888	502,312	7,805,105	344,720	449,626	794,346
F.Y. 1948	169	14,220	1,399,971	503,641	7,668,499	353,179	467,129	820,308
F.Y. 1949	179	17,140	1,769 240	437,903	7,721,865	349,117	573,882	922,999
F.Y. 1950	222	22,828	2,542,564	518,566	9,421,220	538,812	726,973	1,265,785
F.Y. 1951	243	25,352	2,558,091	721,938	15,941,940	548,608	886,250	1,434,858
F.Y. 1952	252	27,933	2,501,317	609,562	13,924,940	537,160	985,902	1,523,062
Total		186,127	18,572,816	5,096,938	$70,805,417	$4,054,264	$6,234,606	$10,288,870

* 262 projects.
† F.Y. 1940 and F.Y. 1941 accomplishments combined.

PROTECTION AGAINST LOSS OF SOIL AND WATER

A well-managed woods helps protect the individual farmer from loss of soil and water, and from loss caused by deposits of sediments. Studies near Zanesville, Ohio, showed the annual water loss from an acre of forested land averaged only one-ninth as much as from an acre of cultivated land. A six-year study at Guthrie, Oklahoma, showed the average yearly runoff from old-growth woodland with a 5.17 per cent slope was but 0.2 per cent. From soil with a 7.7 per cent slope planted continuously to cotton, the runoff was 14.22 per cent. The yearly soil loss was 0.017 ton per acre from the old-growth woodland and 24.29 tons per acre from the cotton land.

QUESTIONS

1. Why is interest in woodland farming increasing?
2. What determines the suitability of soil for tree production?
3. How does soil texture affect tree growth? What trees grow best in sandy soils? Loamy soils? Clay soils?
4. Why is site quality important in woodland management?
5. What is the best site quality for red pine?
6. How are soil characteristics related to site index? What is meant by a site index of 90?
7. How does total rainfall affect site index?
8. What is meant by texture depth index? Why is it important?
9. What qualities are necessary for good tree soils?
10. How has cultivation affected our soil's ability to grow trees?
11. Why is it necessary to fit the tree to the site?
12. How do trees rate as a money crop?

20

Planning the Farm Program

THE purpose of farm or ranch planning is to develop a sound soil and crop management program. It maps a course of action to achieve this goal. The farm plan utilizes the knowledge, experience, and desires of the farmer and the skill and knowledge of the planner.

Information contained in the soil survey forms the basis for planning land use. The first step in this procedure is to develop a "Technical Guide." The Technical Guide is used by those making the plan.

TECHNICAL GUIDE

The Technical Guide is a detailed coordinated arrangement of technical information. It is information suited to a particular area. It contains an analysis of the physical conditions of the land. This includes soils, topography, and erosion conditions. It also contains interpretation for various uses, relation of physical conditions with recommendations for use and treatment of the land, and description and specifications of all needed practices.

PURPOSE OF THE TECHNICAL GUIDE

The need for a reliable guide for the development of sound farm plans is evident. Procedures used in making sound conservation plans need to be clear. These procedures are described in the technical guide. This makes possible uniformly high caliber work on the ground.

The development of the technical guide is a combined effort. It

contains thinking on the part of all individuals working in the area for which the guide is prepared.

It is the means of adapting broader technical recommendations to local conditions. This brings about better understanding and a more practical work plan.

It provides a logical association of soil groups and land use capabilities with needed practices. This association provides a standard for technical procedure. The procedure is constantly kept up to date. The guide is a continuing record of all needed technical information.

By following a standard outline, the information is organized in an orderly manner for convenient use. The guide lists the main items in their order of importance. They are soil type, soil group, land capability, land use, and recommended treatment.

It provides a valuable training tool. The very preparation of the guide is an important step in training those who participate. The concise, logically organized statement of procedure in the Technical Guide is important in training employees.

The organization of local technical information increases the usefulness of the guide in farm planning. This increases efficiency.

INTRODUCTION

The material in the Technical Guide for farm planning is for a specific soil conservation district. It is based on research and experience gained through work on proper land use in the area.

The Technical Guide is prepared by the local staff of the soil conservation district to aid farm planners. It helps them in handling the problems in the district area. It helps them in adapting and applying soil and crop management practices needed in the area. The Guide can be adjusted to conform to the scope of the district's program, work plan, and job-ahead plan.

KNOW THE LAND ON YOUR FARM

A farm is made up of several different kinds of land. Changes in soil, slope, erosion, or sedimentation make these differences. Each kind is suited to certain farming uses. Most areas also have definite limits to their use. The different kinds of land are divided into eight land capability classes. However, they do not all occur on every

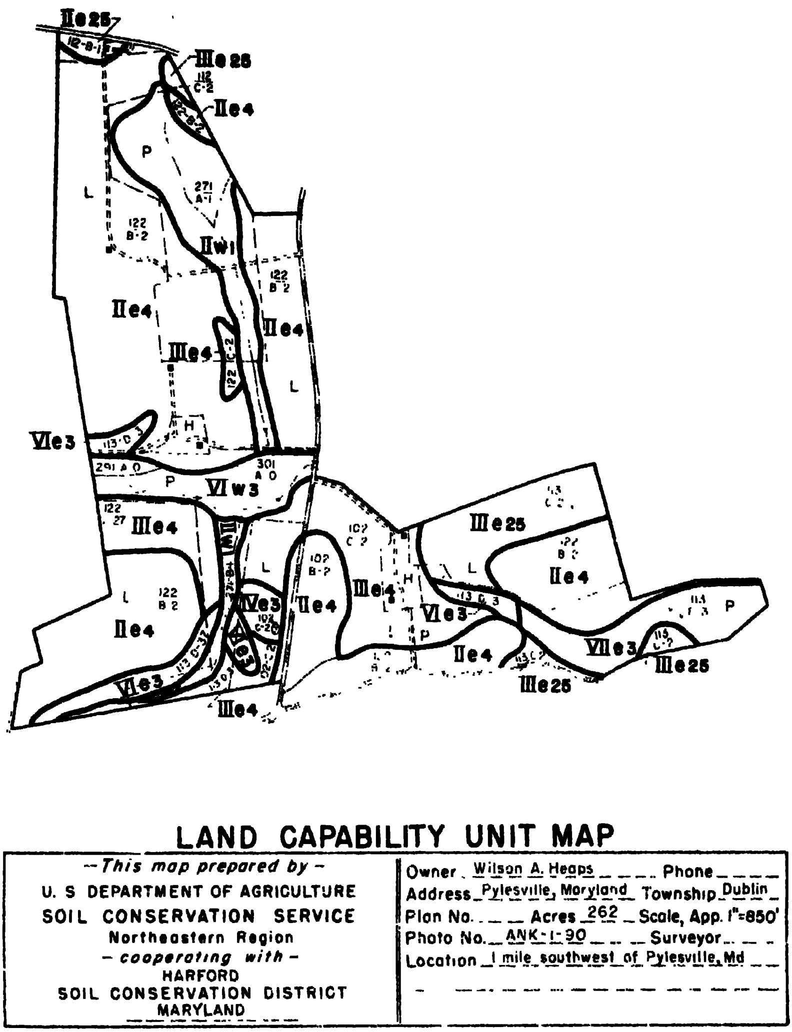


Figure 20-1. Land capability unit map. (Soil Conservation Service Photo)

farm. Classes I through VIII indicate successively fewer choices of safe or economical use.

To make the best use of the land, one should know the kinds of land on the farm. The land capability map in Figure 20-1 shows the land classes on a Maryland farm. Each capability class is further divided into subclasses and land capability units. They are shown

Figure 20-2. Farm planner discussing new farm plan with farm-owner in California (Soil Conservation Service Photo)

by symbols on the map (IIe 4, IIw 1, IIIe 25, VIe 3 etc.) Determine from the land capability map the kinds of land on the farm, then decide how each kind should be used.

Some of the practices and treatments can be safely started by the farmer without assistance. Instructions furnished the farmer explain how this can be done.

There are other treatments and practices that are more complicated. On these the farmer needs help. The soil conservation district provides the farmer with on-the-farm technical assistance. These technicians supply information to help the farmer in deciding how to use and treat each field on his farm.

Following are the recommended procedures for the use of each kind of land on the farm.

IIe 25

This is nearly level or gently sloping, deep, well drained land. The loamy soils are easy to till and may be severely eroded. They are moderately productive. They are well suited for corn and general farm crops.

If used for crops. Farm in contour strips to prevent gullies and

soil wash. Use a rotation of not more than two years of row crop, small grain, and hay. Seed a cover crop or winter grain after each cultivated crop. Keep natural draws in good sod. Lift tillage implements when crossing sod waterways. Seed red clover, timothy, and alsike clover for short-term hay. Use plenty of lime and fertilizer for high yields.

If used for hay. Establish by seeding in contour strips Red clover, orchard grass, alsike, and alfalfa or timothy and alfalfa should do well. Use plenty of lime and fertilize annually

If used for pasture. When seeding, plow or disk in contour strips Seed a tall grass and legume pasture mixture Orchard grass and alfalfa or orchard grass, ladino clover, and redtop may be used Excess forage may be cut for hay or silage Set up a rotational grazing plan Mow just before removing cattle This controls weeds and stimulates new growth Avoid pasturing too early in spring or too late in fall Apply lime as needed and fertilize annually with a high phosphate-potash fertilizer

To improve woodland. Protect from fire and grazing and be on the lookout for diseases Harvest mature trees for sale or farm use Cut or girdle inferior trees that may be shading good young trees Interplant large open areas with white pine and Scotch pine Keep woodland edges in place Do this by removing large trees along the edge This encourages shrubs A woodland border may also be established by planting desirable shrubs

To improve wildlife conditions. Wildlife may be increased by planting hedge fences and windbreaks or by removing trees from hedge rows Plant trees and shrubs on odd areas This furnishes protection for both wildlife and the land

IIw 1

This is flat or gently sloping land Crops are apt to be late in the spring because of wetness This land will produce general farm crops but is best suited to hay

If used for crops. Farm sloping land in graded strips Bed flat land with graded dead furrows Open ditches or diversions may be used to improve drainage Keep natural draws in sod Do not use more than two years of row crops or less than two years of hay in the rotation Select grass legume mixtures that are tolerant of wetness Lime and fertilize for the legumes

If used for hay. Seed in strips on controlled grade Use a mois

ture-tolerant, long-lived grass-legume mixture. Lime and fertilize to maintain the legume. Open ditches, diversions, or graded dead furrows are often needed to improve drainage.

If used for pasture. When reseeding, plow in strips on controlled grade. Use a tall grass-legume mixture. Mow weeds and rank growth. Scatter droppings. Divide pasture and rotate grazing. Avoid early spring or late fall grazing. Lime and fertilize to maintain legumes.

III e 4

The soils are deep, well drained, easily worked, and hold moisture well. The slopes are moderate but erosion has removed up to three-fourths of the original topsoil. The land is suitable for commonly grown crops and responds well to fertilizer. It may be low in potash and may need boron for alfalfa. This land is suitable for rotation cropland. Conservation measures are needed.

If used for crops. Keep in legume hay at least two years out of four. Use contour cultivation on short slopes or contour strip cropping on long slopes. Diversions may be needed on longer slopes. Provide safe outlets before diversions are constructed. Seed a winter cover crop like rye grass and vetch when land is not in winter grain. Red clover with timothy or orchard grass is a good hay mixture. Alfalfa or alsike may be added. Lime for the legumes. Fertilize small grain when seeding. Topdress hay annually with a high potash fertilizer after first cutting. Reinforce manure application with superphosphate.

If used for hay. Reseed by disking in strips across the slope. Reseed as often as necessary to re-establish legumes. Seed to grass-legume mixtures that have a long life Add ladino clover to mixtures if used for pasture. Fertilize to establish seeding. Topdress annually with high potash fertilizer after first cutting. Reinforce manure application with superphosphate.

If used for pasture. Lime and fertilize. Topdress every other year with fertilizer or manure. Mow at least once a year Control grazing in early spring and late fall. Rotate grazing between fields.

III e 25

The deep, open, loamy soils are productive. This land may have considerable slope and may wash severely. It responds well to lime

and fertilizer when protected from washing. It is well adapted to general farm crops.

If used for crops. Cultivate not more than one year out of five with at least three years of hay. Farm in contour strips of alternate row crop, small grain, or hay. Keep waterways or natural depressions in sod. Use diversion terraces on slopes that are subject to washing. Provide safe outlets for diversions before construction. Alfalfa, timothy, red clover, and alsike clover should do well for hay. Lime as needed and fertilize to maintain legumes.

If used for hay. Establish by plowing or disking in contour strips. Alfalfa, orchardgrass, and alsike clover should do well. Smooth brome grass may be substituted for the orchard grass. Lime and fertilize as needed to keep the legume in the stand.

If used for pasture. Establish in contour strips. Make a tall grass seeding. Orchardgrass, ladino clover, alsike clover, and red top will do well. Mow just before removing cattle to control weeds and stimulate new growth. Manage in a rotational grazing plan. Lime as needed and fertilize annually with heavy applications of phosphate-potash fertilizer or phosphated manure.

IV e 3

This is steep, rolling, or eroded land, best used for hay or pasture The soils are well drained throughout and need plenty of lime and fertilizer. But if properly treated they will produce satisfactory hay or pasture. Because of the erosion hazard, this land should be kept in hay most of the time.

If used for hay. Row crops should seldom be grown. Reseeding can be safely done through small grain, or directly from sod to hay. Reseed in contour strips. Diversions may be needed. Provide safe outlets before constructing diversions. Natural draws should be kept in sod. Select and seed grass-legume mixtures having a long life. Alfalfa is adapted if well fertilized. Disking or shallow plowing and disking should be used so that crop residues are left on the surface. Use heavy applications of complete fertilizer at time of seeding. If small grain nurse crop is used, remove either by grazing or as grain hay. Topdress annually with a high potash fertilizer. Boron may be needed for alfalfa-grass mixtures. Add ladino clover to all mixtures to fill in where the other legumes die out. Reseed only as often as necessary to reestablish legumes.

If used for pasture. For tall grass pastures, select seed mixtures

that hold up well under grazing. Use heavy applications of complete fertilizer at time of seeding. Topdress every other year with a phosphate-potash fertilizer. Kentucky bluegrass, wild white clover pasture should be limed before applying fertilizer. Treat critically eroded areas. Seed, fertilize, and mulch. Clip weeds and rank growth at least once a year. Rotate and control grazing. Contour furrows may be used to hold back runoff. Stock water developments may be needed.

VI e 3

This is steep land subject to serious erosion. The subsoil may contain some limey material. It should be kept in pasture or woods. The soils are highly erodible, but will produce fairly good pasture if properly managed.

If used for pasture. Lime before applying fertilizer. Topdress regularly. Slope, seed, and mulch critical areas. Rotate and control grazing. Develop water supplies.

To improve woodland. Keep stock out, protect from fire, and watch for tree diseases. Cut mature or inferior trees that are shading good young trees. Keep woodland edges in place and protect woods from damage by developing or planning a shrub border. Land that cannot be managed by mowing, liming, and fertilizing to keep a dense vigorous sod should be reforested. These soils are capable of growing quality timber.

VI w 3

This is nearly level bottomland that may have been eroded from streambank overflow. The soils are loamy and may be wet in the subsoil because of a high water table. Because of the possible damage to crops by stream overflow, these soils are best adapted to permanent pasture.

If used for pasture. Establish by disking in small plots or strips. Ladino clover, orchardgrass, or timothy and alsike clover should do well. Bluegrass and white clover are well adapted. Use a complete fertilizer at time of seeding. Maintain by heavy annual application of high phosphate-potash fertilizers. Lime as needed. Manage grazing. Mow just before the end of each grazing period to control weeds and stimulate new growth. Avoid early spring and late fall grazing.

To improve woodland. Protect from fire and grazing and guard

against tree diseases. Harvest mature trees that have been marked by a qualified person. Cut or girdle worthless trees. Confine woodland edges by establishing a border of wildlife shrubs.

To improve wildlife conditions. Plant eroding streambanks and odd areas with silky cornel, purple-osier willow, highbush cranberry, or tartarian honeysuckle.

VII e 3

This is steep or badly eroded, droughty land, best used for woodland. This land is low in fertility. Tree growth is usually not rapid, but fair timber or pulpwood can be produced with good management.

To improve woodland. Areas not covered by existing woods should be planted. Black locust can be mixed with the pines to help increase soil fertility even though they may die before reaching fencepost size. Because of slowness of growth and the type of trees generally found, cutting for pulpwood is the main management problem. Protect from fire and grazing. Keep woods from crowding crop or pasture fields by planting or developing a shrub border.

To improve wildlife. Allow den trees to remain in woods. Plant suitable shrubs along woods roads and in open areas to improve cover for wildlife.

QUESTIONS

1. What is the purpose of farm and ranch planning?
2. How is the farm plan developed?
3. What is the Technical Guide? What does it contain?
4. What is the purpose of the Technical Guide?
5. To what area does a Technical Guide apply? How is it prepared?
6. How does the Technical Guide help in planning a farm program?

21

Farm Surface Water Disposal System

EVEN with effective erosion control programs, there will be times when more water falls than the soil can absorb. This is particularly true during heavy rains or rains extending over several days.

This excess water presents another phase of the soil erosion control problem. At times it can be serious. During these periods plant cover must be reinforced. It must be supported with appropriate mechanical measures. The object of the mechanical measures is safe disposal of the excess surface water.

The measures used have two main purposes. One is to collect the excess water. The other is to conduct the collected water off the field in the least damaging way.

Excess water must be collected and disposed of so as to do the least damage possible. Free water must not be allowed to run over long, unbroken slopes. Neither should it be allowed to run over bare ground or at high velocities. If it flows over long, unbroken slopes or at high velocities, water tends to cut gullies. Where allowed to flow over bare ground, it is sure to damage the land.

The purpose of mechanical control measures is to prevent scouring: that is, to prevent gullying. Their duty is to prevent the 5 to 10 per cent of erosion not caused by raindrop splash. Their function is to control from 5 to 10 per cent of the erosion on our farms.

To achieve this, two main objectives must be achieved. First, long slopes must be shortened. Second, the flow of water must be slowed

enough to do the least amount of damage. A part of the second objective is also to prevent flowing water from coming in contact with bare ground.

Slopes are shortened by the use of terraces, contour cultivation, and diversion ditches. These also slow the rate of flow. Water in channels is kept from coming in contact with bare ground by seeding the channel bottom and sides to grass.

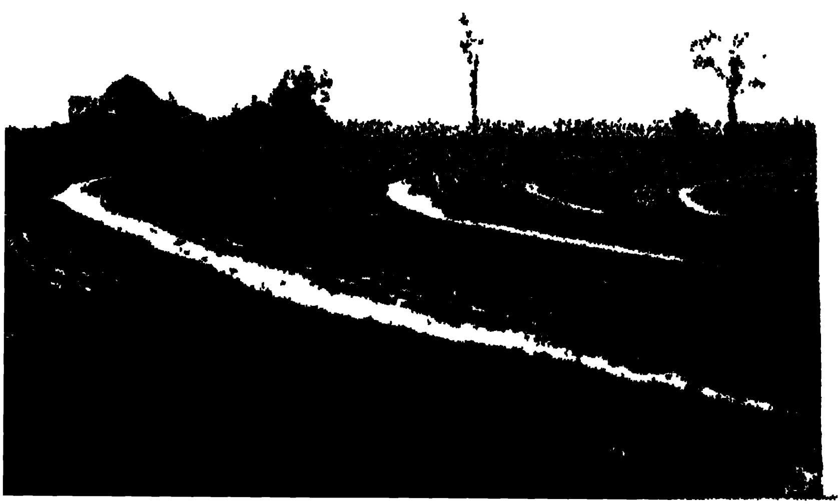
The main purpose of these measures is to deal with excess surface water. They make up the surface water disposal system. The information used in planning this system is obtained by means of hydrologic surveys—surveys of excess water or, better still, surveys to determine how much excess water there will be.

The surface water disposal system also includes check dams, grassed waterways, streambank protection, and other water control measures.

TERRACING

Terraces are hillside ridges. They are laid out approximately on the contour. They have wide, shallow waterways along the uphill

Figure 21-1. Terraces are hillside ridges, approximately on the contour, which form wide, shallow waterways along the uphill side of the ridge. They are used to check scour erosion caused by runoff from cultivated land. This terraced field is in Connecticut. (Soil Conservation Service Photo)



side of the ridge. They are used to control runoff from cultivated land. Level terraces are sometimes used to conserve water. They are used in arid and semiarid areas. They should be used on soils with high infiltration rates. They should be used especially where such soils are underlain by permeable subsurface materials. Those built for safe disposal of excess water have gentle grades.

Terraces may be built either before cultivation or before seeding preparation. Water disposal terraces usually have grades less than three inches per 100 linear feet. Terraces should empty into grassed waterways. The waterways then conduct it off the field safely.

Terraces are made with a variety of equipment. They may be made with disk plows or grader equipment. These implements dig out a channel. They pile the excavated material in ridges along the lower side. The ridge ordinarily is fourteen to sixteen inches high. This creates a channel with a cross-sectional area of from eight to twelve square feet. The ridge should be flat and broad enough so it will not interfere with the operation of machinery on the contour.

Climate, kind of soil, and steepness of slope are considered in determining terrace spacing. The vertical drop in feet, between ter-

Figure 21-2. *Meadow strip terrace outlet channel in South Carolina. The grass protects the channel and produces a hay crop in addition.* (Soil Conservation Service Photo)

Figure 21-3. A diversion ditch has been constructed high up on the hillside to intercept water from higher up the slope and conduct it safely off this field in Lancaster County, Pennsylvania (Soil Conservation Service Photo)

races on slopes with three to six feet fall in 100 feet of slope, is determined as follows

$$\frac{\text{Slope face in feet per 100 feet} + 2}{2}$$

For slopes of seven to twelve feet fall per 100 feet of slope, use the following

$$\frac{\text{Slope} + 6}{3}$$

For slope of zero to two feet fall per 100 feet of slope, terraces are often arbitrarily spaced 100 feet apart horizontally Formulas have been developed for various communities These more nearly fit local conditions of soil, climate, and rainfall

Cultivation on terraced land must be conducted on the contour with the terrace.

DIVERSION DITCHES

Diversion ditches are dug high on hillsides. They are dug across sloping land. They intercept and divert surface runoff from lines of natural drainage. They divert water. This keeps the water from piling up at the bottoms of hills. Lowlands are protected from overflow. Where possible, areas above the ditch should be maintained in vegetation. Vegetation prevents both splash and scour erosion. Runoff water will not be loaded with soil.

Design. Generally, the cross section of diversion ditches is designed for maximum water-carrying efficiency. It should require as little earth moving as possible. The upper side should be flat. This reduces scour erosion by water entering the channel.

Diversion ditches are ordinarily laid out on the maximum nonerosive grade. If the channel is bare, the grade should not exceed 0.4 foot fall per 100 linear feet. In highly erosive soils, the fall should not exceed 0.2 foot. The grade should be such that the velocities will not exceed those safe for the soil—and vegetation, if the channel has been seeded.

The location and design of diversion channel outlets are important. A wide, flat, well-vegetated outlet spreads the water in a thin sheet. This reduces erosion. Outlets of ditches emptying into gullies or channels on steep grades should be protected. This protection may be in the form of check dams, chutes, vegetation, or drop inlets. Each channel should be lined to make its bottom and sides stable and thus protect them from erosion.

Diversion ditches should be constructed from the upslope side of the channel. Excavated material is piled to form a ridge on the downslope side. This increases the depth of the channel. Ordinarily, vegetation should be established as soon as possible.

Regular maintenance is required to keep out bushy or woody growths. These obstruct flow and cause silt accumulations.

CHECK DAMS

Protecting channels means preventing injurious erosion in waterways—within the flow channels. Check dams are one method Temporary materials such as brush, wire, and logs are used. They are placed at frequent intervals across the bottom of a channel. They protect the channel until it can be sodded. The vegetation gains

Figure 21-4. Gully controlled with bands of Bermuda grass sod in Paluski County, Arkansas (Soil Conservation Service Photo)

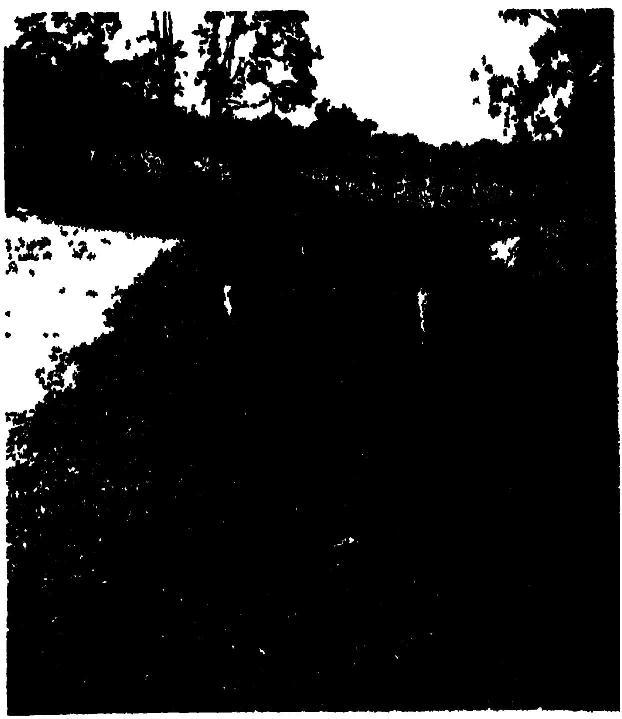


Figure 21-5. Permanent check dams assist grass sod on this steep slope in Washington County, Maryland. (Soil Conservation Service Photo)

control during the life of the dam. When the dam decays it need not be replaced. In some cases 12-inch strips of grass sod are used. They are placed at regular intervals across the waterways.

In some cases, vegetation alone is not strong enough. In these cases, vegetation must be supported with permanent dams of concrete or other long-lasting materials.

Downstream grades. To be effective permanent control structures must have stable downstream grades. That is, they must not erode. In such cases, it may be necessary to build several structures. These structures should be built in the lower end of a channel first. They should be constructed from the downstream end up the slope to the channel head. A stable grade exists when the channel is neither aggrading (filling) nor degrading (scouring). Several factors affect grade stability. The most important are velocity, amount of vegetation in the channel, straightness, sediment carried in the flow, and erodibility of the soil.

Overfall structures. Water often enters the head (upper end) of

Figure 21-6. *Check dam made of bundles of willow cuttings laid in a trench across the gully between the rows of willow stakes in Santa Cruz County, California. The gully will be planted to suitable vegetation for final control.* (Soil Conservation Service Photo)

a gully by an overfall. In this case a structure may be needed to check the overfall erosion. Overfall structures must be located to establish a nonerosive grade. The grade must be nonerosive from the place of overfall to the crest of the spillway[1] below. This grade depends on soil conditions. It may be determined by studying the grades of existing gullies and channels in like soils which appear to be stable.

The safety of a check dam depends on the downstream grade and capacity of the spillway.

BANK PROTECTION

There are two general classes of bank protection. One slows the flow along the banks, causing the silt to be dropped. The other protects the bank directly. The bank is covered with brush or other material to slow the flow of water at ground surface and reduce erosion damage.

Brush mats. Brush mats with shrubs or tree plantings may give very good results. This may be an expensive type of construction because of hand labor involved. A brush mat has a short life. Its main function is to provide a mulch to assist in establishing a dense growth of vegetation. The banks may be sloped and the brush mat laid at any season. The plantings are made through the mat.

Willows are usually the best planting materials. The brush is laid in shingle fashion with the butts pointing up the bank. The mat may vary from three to eighteen inches in thickness. This depends on the site of the stream and quantity of floating ice, logs, or other heavy material. The mat is held in place by stakes driven in at an angle crossing each other in pairs.

Another way is to drive stakes straight into the ground. They are arranged about two feet, six inches apart on centers and interlaced with galvanized wire. After the wire has been attached the stakes are driven at an angle to increase the tension. Some of the details of a brush mat are shown in Figure 21-6.

GRASS-LINED WATERWAYS

Grass-lined waterways make up an important part of the farm water disposal system. Wherever natural sodded waterways are available, they should be used and should be carefully maintained.

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[1] A passage for overflow water in a reservoir.

They are the best type of channels for collecting and carrying excess surface water.

Where terrace systems are installed, new drainage channels must sometimes be made. New channels should be lined with vegetation. Whenever plant covers protecting drainageways are seriously damaged, they should be re-established. When establishing a grass-lined channel, a suitable grass should be used. The grass selected should be able to stand up under flowing water. It should also be able to protect the channel from scour.

The Soil Conservation Service conducted studies to determine the water flow characteristics of vegetation in channels. These studies were made at outdoor laboratories near Spartanburg, South Carolina, and Stillwater, Oklahoma. Those at Spartanburg were conducted under field conditions on a rather steep hillside along a small stream in the Piedmont Plateau. The information thus obtained is applicable to the design of similar channels in the field.

These studies dealt with plants adapted primarily to the Southeastern and South Central States. Studies were carried out with Bermuda grass, common lespedeza, sericea lespedeza, and a mixture of orchardgrass, red top, and Italian ryegrass. Tests were made also on centipede grass, Sudangrass, dallisgrass, crabgrass, and other plants. A channel lined with kudzu was used to test the effect of seasonal conditions and growth on stream flow.

Crop production factors studied were growth, season, and channel maintenance conditions. The slope of the channel bed ranged from 1 to 24 per cent. In most instances, it was either 3 or 6 per cent. Two general types of channel were used, the trapezoidal and the rectangular. Both channels had flat bottoms. The walls of the trapezoidal channel sloped outward. Those of the rectangular channel were vertical or at right angles to the bottom.

The protective capacity of each channel lining was measured. The measurement was made by determining the highest rate of flow the lining could withstand without being torn out by water.

The results of the experiments showed that the effectiveness of channel vegetation depends on the degree to which the top of the vegetation is bent and flattened by the flowing water. This in turn depends mainly on the physical characteristics of the vegetation. It also depends on the manner of growth of the vegetation and the velocity and depth of the flowing water.

Findings from the study are also applicable in other areas where

the same or similar types of vegetation may be used as channel linings.

Three water flow characteristics were covered in the studies. They were (1) resistance offered to flow by the vegetation, (2) protection offered the channel bed, and (3) effect of vegetation on how water flowed in the channel.

Resistance to flow. Flowing water acts similar to wind in the erosion process. Flowing water drags as it moves along the surface of the channel, the same as wind drags or pulls along the surface of the ground.

With wind, the velocity at the surface of the ground is known as drag velocity. The amount of drag is determined by the velocity at the ground surface. As the ground surface is roughened, as by clodding or by establishing plant cover, the drag velocity of the wind is slowed down. If sufficient obstructions are placed in the path of the wind, that layer of air in direct contact with the ground becomes more or less stationary. It loses its drag. Consequently, it has no capacity to erode.

At the same time, the layer of air immediately above that in direct contact with the ground does possess velocity. So does each of the other layers higher up in the air mass. In fact, the velocity of each successively higher layer of air is greater than the one immediately beneath. These progressively higher velocities of air make dust clouds possible, once fine dust particles have been bounced off the ground.

And so it is with flowing water. As flowing water moves along the surface of a channel it drags or scours. It too has drag velocity. The erosive power is proportional to the drag velocity, which is greatest on bare, smooth surfaces. However, as the friction is increased, the velocity is lowered. It loses some of its drag. If the bottom and sides of the channel are roughened sufficiently, or a dense enough sod is established, the layer of water at the immediate ground surface becomes stationary and loses its drag or power to erode.

But with flowing water, as with wind, each successively higher layer of water encounters less obstruction. And so, having greater freedom to move, it flows faster.

Grass channel linings resist the flow of water. The grass roughens the surface and obstructs the flow of water at the ground surface. It reduces the water's drag velocity—its eroding power.

Plants are most effective in reducing the rate of flow when the

water is shallow. In this case, the plants stand up in the flow. They are neither bent nor covered and thus offer the greatest resistance to flowing water. The layer of water at the ground surface stops flowing. It does not erode.

As the depth of the flow increases, the water gets deeper. And, too, the grass is less dense toward its top than at the ground. Therefore it offers less and less obstruction as the flow depth increases. Eventually the water gets deep enough to bend the grasses over and submerge them.

The resistance to flowing water at the point where grass is submerged starts decreasing. The flow increases rapidly as the depth of water above this point increases. When bending and submerging is completed, the resistance begins to level out and the water soon approaches a steady rate of flow. The most rapid change in the rate of flow takes place at the point where the grass is submerged and steady flow develops.

Even though the portion of water above the grass flows faster than that at the ground surface, it does no damage, because it has no contact with the ground. However, it can carry large loads of silt and clay in suspension: material splashed up by raindrops or scoured loose from bare surfaces in the channel by the flowing water.

Grass-lined channels are usually broad and shallow. They are designed to handle flows represented by the range of most rapid change in velocity, or the velocity just above the bent and submerged grass.

The most important job of the grass in a grass-lined waterway is to prevent scour. The measures of protective ability of grass is the greatest velocity to which it will protect the channel from serious erosion. In the studies at Spartanburg and Stillwater the protective value of a number of grasses was determined.

The safe velocity for grass depends on its kind and quality and on the texture of the soil in the channel bed. Sod vegetations have the highest safe velocities. Clumpy bunch grasses have the lowest. Sods give complete protection to the channel bed. Bunch grasses have bare areas between the clumps. In addition, turbulence develops around a large clump of vegetation, causing local scour. Channel slope also affects safe velocity. The steeper the channel, the lower the safe velocity, because of the turbulent flow in the steep channels.

A grass-lined channel must be built to carry the expected flow without overtopping or eroding. The first requirement is met by

making the channel large enough. The second is achieved by selecting a channel cross-section to keep the mean velocity below safe.

Constructing grass-lined waterways. Whenever possible, the runoff water should be diverted from the waterway until vegetation has become established. This is sometimes done by constructing a protective dike at the head and along each side of the new channel. After the grass in the waterway has been established, this dike should be removed. Where such diversion is not possible, the seedbed may be protected with burlap or straw mulch. Straw should be covered with wire mesh or secured in some other way.

Careful design is important to secure adequate inlet and outlet. It is also important to make certain that short and infrequent runoff in excess of the design flow will not cause excessive damage. In many instances the low flows are carried in lined channels. Then additional capacity in the form of a vegetated channel can be provided to handle a portion of the infrequent larger flows. This reduces the cost of the channel lining by reducing the cross-section.

Where gullies exist in waterways selected as a part of the water disposal system, they should be filled. This can be done by plowing or blading in the banks. The banks should be sloped to secure the desired cross-section. All fill material should be mulched and compacted. It should be made firm enough to provide a good seedbed.

Waterways can be made productive. In addition to handling excess water, grass-lined waterways can be made into productive parts of the farm if they are carefully established and properly managed. In many places they are developed into regular hay fields. In other cases waterways are used to produce grass and legume seed. All of them can be pastured at certain times of the year.

The right kind of grass is important. Grasses must have certain characteristics to be satisfactory in channels. They must have compact root systems. They must grow thick on the ground. And they must flatten out under running water and straighten up when the runoff stops.

Bermuda grass is one of the best for use in waterways in the South. It has a deep, compact root system and a short, dense growth. It is adapted to a wide range of soils.

Kentucky bluegrass is an ideal grass for channels in soils that are high in organic matter. It has a dense root system that grows close to the surface. The top growth is moderately short and thick.

Chewings fescue is similar to bluegrass. In addition, it grows on

soils low in organic matter, such as sands. Timothy is well adapted to a wide range of soil conditions but it is a bunch grass. It must be used with other grasses, like redtop, to form a thicksod. The root system of bromegrass is deeper than that of bluegrass but is not so dense. It is particularly well suited to deep, fertile soil.

Tall fescues are excellent wetland grasses. They stand up well under a heavy flow of water. Reed canary grass also grows in wet soils, but it should be used only where there is a deep, well-defined waterway. It is not suited to shallow waterways. Its tall, dense growth causes silting. This makes a dam across the waterway. These dams may force the water out of the channel or make it wander back and forth in the channel.

Good seedbed essential. Preparing a good seedbed is the key to getting a good stand of grass in the waterway. If the field is being seeded to meadow, the seedbed can be prepared for the waterway at the same time, using the same tools. Some extra work needs to be done in terrace outlets and other specially built channels.

Barnyard manure at the rate of ten to twenty spreader loads per acre as a mulch after seeding produces good results. Lime, usually one to two tons per acre, can be worked into the soil when the seedbed is being prepared. If manure is not available, use liberal amounts of a suitable commercial fertilizer.

Use good seed. High-quality, live seed is a necessity. Use two or three times more seed than ordinarily used for meadows. Sow seed shallow—one-quarter to one-half inch deep if a drill is used. Put the seed on top of the ground if it is sown by hand.

Seed a simple mixture. The seed mixture should be simple. That is, it should contain only a few kinds of seed. In fact, one grass with a short-lived companion crop usually is enough. Grasses having different growth habits may compete with each other. This competition may weaken some of the species. In many places, it is not advisable to use a legume, but in the South, kudzu and sericea lespedeza make excellent waterway linings. Caley peas and reseeding crimson clover are also used as winter legumes on summer grasses.

Fertilizer needed. More fertilizer is needed to maintain a good sod in waterways than on most field crops. The area occupied by the waterway is vulnerable. Grass must be established quickly and properly maintained. The waterway can also be used for producing hay or other forage. If a drill is used, the fertilizer can be applied with a

fertilizer attachment. When the seed is broadcast the fertilizer can be broadcast at the time the seedbed is prepared.

Mulch after seeding. After seeding, spread a light mulch at the rate of about two tons per acre. Use straw manure, small grain straw, or other suitable material for mulch. Then cultipack to cover the seed and press the mulch into the soil.

Seed in early spring or late summer. Successful grass seeding can be made during early spring or late summer. If the waterway is prepared out of season, it should be seeded with a stabilizing crop to prevent damage from rains. Sudangrass, oats, rye, or similar crops can be used in the spring. For a fall stabilizing crop, use oats, rye, ryegrass, or similar crops.

For fall seeding cut the stabilizing crop four to eight inches high. Remove surplus top growth. This may later be used as mulch after seeding. Then seed the grass mixture with a drill, or broadcast and cultipack. If the ground is dry and hard, it may be necessary to disk before seeding.

Protect waterway while establishing grass. Start protecting the waterway as soon as it is seeded. Divert the water that falls on the rest of the field from the waterway while the grass is getting started. Until the seeding is well established, no water should be allowed to flow over the grass except that which falls directly on it.

Fertilize frequently to keep sod strong. Fertilize the waterway liberally at least once a year. Use the fertilizer treatment being used for other sod crops on the farm. Apply at rates at least one and one-half times that used on sod crops. This is to keep the grass healthy and to produce a dense sod.

Keep the grass in the waterway short if it is not to be mowed for hay or used for seed. A short, dense top growth of grass carries more water without injury to the waterway than tall mature grass with stiff seed stalks. Seed may be harvested from some waterways, but many types of grass provide less protection against washing when allowed to produce seed. For this reason grass in waterways carrying heavy flow should not be allowed to produce seed. And animals, especially hogs, should never have free access to waterways.

Repair when needed. If the grass lining of the waterway becomes damaged, repair it immediately. It will be easy when the damage is small. Each rain increases the cost and labor of putting the waterway back in good condition.

Rills and small gullies may develop in a waterway during rains even when perfect seedings have been established. They are often started by such obstacles as rocks, a broken tree limb, or weeds which cause the water to concentrate in one place. The concentrated water may cut through the sod. Such obstacles must be removed and the scar filled. If the hole is more than three or four inches deep, soil should be tamped firmly and sodded with good live sod. The sod also should be tamped in place.

Always lift plows and straighten disks when crossing the waterway. Plow at right angles to the waterway—never plow parallel to it. This prevents water from running along the side and starting a gully.

The waterway is an important part of your water disposal system. If it fails, the rest of the system is weakened.

Questions

1. Why do we need a farm water disposal system?
2. How does the farm water disposal system handle excess water?
3. What makes up the farm water disposal system? What is the purpose of each portion of the system?
4. How does the farm water disposal system accomplish its mission?
5. What are terraces used for? How do they accomplish this?
6. Why are grassed waterways so necessary?
7. What is a diversion ditch? How is it constructed?
8. What are check dams used for?
9. What are brush mats used for?
10. How does vegetation protect the ground from flowing water?

22

Irrigation

Irrigation is as old as civilization. In fact, irrigation first made civilization possible as we now know it. By irrigation the Mesopotamians were able to produce crops in quantities greater than their own needs. This made it possible for some of their population to do other things than produce food.

Irrigation had been established when the writing of history began. Earlier than 2,000 years B.C. water was diverted from the Nile River to irrigate the desert lands of Egypt.

Irrigation in China is known to be more than 4,000 years old. The famous Tu-Kiang Dam, still a useful dam today, was built in 200 B.C. It provides irrigation water for about one-half million acres of rice fields. The Grand Canal, 700 miles long, was built A.D. 589–618.

Irrigation in America is also old. It was practiced by the Indians at the time of the Spanish Invasion. There are evidences that extensive irrigation works once existed in Arizona and New Mexico. It is believed that some of these canals were built about A.D. 700. Most of these earlier irrigation systems were abandoned before white men came to this continent. However, many of the Indians of the Southwest were practicing irrigation on a small scale.

Irrigation was also practiced by the Spanish padres at the early missions in California. They irrigated gardens, orchards, vineyards, and some small grain fields. Irrigation was also practiced by trappers, miners, and frontiersmen in many places in the West. However, no effort was made to develop an agricultural economy based on irrigation until the Mormon pioneers entered Salt Lake Valley in July, 1847. This was the beginning of modern irrigation in America.

From the first, irrigation was a cooperative undertaking. Communities were located on the streams flowing from the mountains. Community ditches were constructed to serve both the outlying agricultural areas and the garden plots in the towns.

The second important irrigation development was the establishment of the Union Colony at Greely, Colorado, in 1870. This community effort resulted in more than 30,000 acres being brought under irrigation.

From these beginnings, irrigation agriculture spread rapidly throughout the western states. By 1890 the first irrigation census showed a total irrigated area of 3,631,000 acres. This area was about doubled during the next decade, and doubled again by 1910. The increase in irrigated land was rapid and steady up to 1920. Irrigation water was mostly from surface water supplies.

During the next decade there was only a very small additional acreage irrigated. Most of this was also irrigated from ground water supplies. A relatively small increase occurred between 1930 and 1940. A larger gain was made between 1940 and 1950. Again, the water for this gain came almost entirely from ground water supplies.

IRRIGATION AND FOOD PRODUCTION

With the population increase expected, there will be 190 million people in the United States by 1975. Our total agricultural cropland has remained about the same since 1920. However, the farm output index has increased from 92 in 1920 to 138 in 1950. Since 1935 the equivalent of about 45 million acres of cropland has been released from feeding horses and mules. By 1975, another 15 million acres can be expected to be released from this use. It is estimated that about 30 million acres can be added to our cultivated area by reclamation through irrigation, drainage, and land clearing. Of this, about 6 million acres could be brought into production by 1975 through irrigation. This is a big job.

In order to maintain the 1950 standard of diet, we need more land. We need about 577 million acres equivalent of cropland by 1975. This is about 70 million acres more than appears to be available. We need an additional 112 million acres, or a total of 689 million acres, to provide an adequate diet for all. This indicates that we are closer to the day when we will face a food shortage than most of us realize.

More efficient use must be made of both our land and water if we

are to meet these new crop production demands. Land now under irrigation must be managed to get the maximum returns from the water available. And, too, additional acres must be brought under irrigation. New sources of water for irrigation must be found. This applies to old irrigated areas as well as the humid area of the eastern section of the United States. In short, every acre of land and every gallon of irrigation water must be made to produce their most.

IRRIGATION ELIMINATES DROUGHT HAZARD

Irrigation has long made it possible to produce bountiful crops in arid climates. Good crops would not be possible without irrigation in these climates. During recent years, we have found that irrigation eliminates drought hazards in the East too. We find that by supplementary irrigation crop production can be greatly increased in most years in the humid section.

Adequate moisture, combined with ample plant food and good management, enables crops to produce top yields. For example, properly prepared and managed irrigated pastures in Washington produced two to three times as much beef per acre as unimproved irrigated pastures. The unimproved pastures consisted mainly of Kentucky bluegrass. The amount of beef produced averaged 200 to 250 pounds per acre on the unimproved pastures. The improved pasture produced an average of 549 pounds of beef per acre annually. This study extended over a four-year period.

Supplementary irrigation in summer of Bermuda–Ladino clover pasture in Georgia increased the production of forage 27 per cent. Protein production was increased even more. It was increased 67 per cent. Greater survival and growth of Ladino clover with irrigation accounted for both the increased forage and protein production.

It has been shown that cotton in Texas has a critical need for water during the fruiting period. If adequate moisture is not available at this period yields are reduced. In addition, the cotton produced is of inferior quality. It has a shorter staple length.

Studies in Florida show it is unsafe to try to grow vegetables without irrigation. Irrigation does not pay on all crops each year, but it insures a crop. Irrigation paid big dividends in years of low rainfall. It assures the farmer of a full crop whether there is ample rain or not. Irrigation often means the difference between a successful harvest and crop failure.

CONSUMPTIVE USE OF WATER AND IRRIGATION REQUIREMENTS

Water is the limiting factor in the expansion of irrigated agriculture. Thus, in irrigation planning, it is essential that consumptive use and irrigation water requirements be known. This is true both for large irrigation projects and for individual farms—whether in the arid West or in the humid East.

Consumptive use means the amount of water required to produce a crop. It includes water lost by evaporation from the soil as well as that lost by transpiration by plants. It is referred to as evapotranspiration losses. Evapotranspiration is the index of how much irrigation water is needed for good production.

CONSUMPTIVE USE

The term consumptive use, as used here, is synonymous with evapotranspiration. It is defined as the sum of the volume of water used by vegetative growth and that evaporated from the soil. Water used by plants in building tissue is given off through the leaf surface or transpired. If the unit of time is small, consumptive use is expressed in acre-inches per acre or depth in inches over an acre. But if the unit of time is large, such as a crop-growing season or a twelve-month period, consumptive use is usually expressed as acre-feet or depth in feet over an acre.

FACTORS AFFECTING CONSUMPTIVE USE

Many factors operate singly or in combination to influence the amount of water used by plants. The effects of these factors are not constant. They fluctuate from year to year as well as from place to place. Some involve the human factor, but others are related to natural influences and the environment.

The rate of evapotranspiration depends on a number of factors. Some of the most important of these are moisture supply, vegetative cover, soils, and land management. The climatic factors affecting consumptive use are precipitation, temperature, humidity, wind movement, and length of growing season. Also the quantity of water transpired by plants depends on the amount at their disposal. Certainly, if there is a limited supply, water use will be small.

STUDIES AND RESULTS

Research studies have been made on evaporation and transpiration at various times during the past fifty years in the United States. One of the first studies of this kind was made in California in 1903. At various times and places, consumptive use of water by different agricultural crops and natural vegetation has been measured. Results of these studies show estimated rates of consumptive use of water by each one of the more important crops. Formulas have been developed to determine evaporation and consumptive use of water by using temperature and humidity data.

Various methods have been used to determine consumptive use of water by agricultural crops and natural vegetation under field conditions. Regardless of the method, the problems encountered are numerous. The source of water used by plants, whether from precipitation, irrigation, or ground water plus precipitation, is a factor in selecting a method.

WATER USE AND CLIMATOLOGICAL DATA

Measurements of consumptive use under each physical and climatical condition of any large area are expensive and time consuming. Therefore, some rapid method of transferring the results of measurements, made in several areas, to other areas is needed. Such a method was developed by the Soil Conservation Service. The procedure correlates existing consumptive-use data with a number of local factors. The most important of these are monthly temperatures, percentage of daytime hours, precipitation and frost-free period, or irrigation season. Figures developed for different crops are used to adjust consumptive use data for one location to others where climatological data alone are available.

The use of water is affected by numerous factors. But temperature and precipitation records are the most universally available data. Of all the climatic factors, these elements, together with daylight, have the greatest influence on plant growth.

WATER QUALITY AND IRRIGATION

Crop production under irrigation must always be concerned with the quality of water used. The quality of water influences the irriga-

tion and drainage practices followed and determines the type of crops that can be grown successfully.

All water from surface streams and underground sources contains dissolved substances known chemically as salts. Ocean water contains approximately 3 per cent salts. Waters used for irrigation generally contain less than 0.5 per cent salt.

In common usage, salt is thought of as table salt. However, thousands of different salts are known. Examples of the salts in irrigation water are table salt (sodium chloride), Epsom salt (magnesium sulfate), gypsum (calcium sulfate), muriate of potash (potassium chloride) and baking soda (sodium bicarbonate).

WATERS VARY IN SALT

The total salt content in surface and underground waters varies widely. Mountain streams often contain less than one-fourth ton of salt per acre-foot. Drainage waters and ground waters in desert valleys may contain as much as ten to fifteen tons of salt per acre-foot. In general, the further a stream extends from its origin, the higher its total salt content will be. This is due to the inclusion of more and more valley drainage water.

Ground waters in river valleys often vary widely in total salt content. The content differs at different locations and at various depths.

In addition, waters differ greatly in the kinds of salt present. Some waters are high in table salt and sodium bicarbonate. Others are high in Epsom salt and gypsum.

IRRIGATION ADDS SALT TO THE SOIL

Since all surface and underground waters contain salt, irrigation adds salt to soils. The amount of salt added annually to each acre depends on the total volume of water applied, the amount of salt in the water, the subsoil drainage, and the crop gown.

For example, in the El Paso Valley, approximately 37 inches of Elephant Butte water are applied annually under normal conditions. Since this water contains approximately one ton of salt per acre-foot, the soils in the Valley receive an annual application of three tons of salt. Where water from wells high in total salt content is used, much larger quantities of salt are applied each year. The salt applied remains in the soil unless it is flushed out in the drainage water or is removed in the harvested crop.

SALT ACCUMULATION PRODUCES SALINE CONDITIONS

A saline soil is one in which salt has accumulated sufficiently to reduce crop yields. Salt is applied each year through irrigation. Consequently, any condition or combination of conditions that allows the salt to accumulate in the soil produces a saline soil. Some of these conditions are: frequent and light irrigations where little or no salt is being flushed out of the soil; water application to tight, slowly permeable soils; and poor drainage, which results in a high water table.

The development of saline soils is a process of salt accumulation. Consequently, salinity can be associated with either good or poor quality water. Obviously, the more salt an irrigation water contains, the greater the likelihood for saline soils to develop. Soils that cannot be flushed out and drained readily should not be irrigated for long periods of time with waters high in salt.

SODIUM BICARBONATE AND BLACK ALKALI

Black alkali develops in soils when they are irrigated with waters containing more bicarbonate than calcium plus magnesium. Accompanying the process of black alkali formation are changes in the soil clay. Sodium displaces calcium and magnesium from the clay. The calcium and magnesium are then deposited in the soil as insoluble lime. As a result, soil structure deteriorates. Air and water are then restricted, soil alkalinity increases, and plant growth declines. Often these soil changes are more pronounced when waters low in salt but high in sodium percentage are used.

SALT INJURIOUS TO PLANTS

The salt in irrigation waters is injurious to plants. As the salinity of the soil increases, plant growth is progressively restricted. Immediately following an irrigation, the salt concentration in the soil water of the upper part of the root zone will be about the same as in the water applied. As the soil dries out, the salt in the soil water becomes more concentrated and, consequently, more injurious.

Irrigation with water high in salt content increases the concentration of salt in the soil. The more saline the irrigation water, the more frequently and more abundantly must the land be irrigated. It is necessary to keep displacing the soil water downward to avoid high

salt concentrations in the root zone. The amount of leaching of the root zone—the amount of soil drainage—should be increased if more salty waters are to be used successfully.

ADEQUATE IRRIGATION AND DRAINAGE SOLVES SALINITY PROBLEMS

As pointed out, the salt added with each irrigation remains in the soil. Salt becomes more concentrated unless washed downward with later irrigations. Consequently, the prevention of salinity is a matter of applying sufficient water. Water is applied periodically to flush out the salt left from previous irrigations.

Application of irrigation water creates the problem of drainage. If enough water is applied to keep the excess salt flushed out of the root zone, water moves downward and eventually reaches the water table.

This process raises the water table. As long as the water table remains six to ten feet below the surface, little or no difficulty is encountered. But if the water table rises above this level, the practice of flushing the excess salt downward must be stopped. For, if flushing is continued, the water table moves up into the root zone and waterlogs the soil. Waterlogged soil is poorly aerated and is less suited to plant growth. Under these conditions construction of a drainage system is necessary.

More open and permeable soils are better suited for irrigation because they drain better. Consequently, they can handle salty waters better than tight soils.

For example, water passes through tight clay soils at the rate of one-fourth to one-half acre-inch per hour. In moderately permeable clay loam soils, water passes through at one-half to three inches per hour. In coarse sandy soils, as much as seven to nine inches may pass through per hour. For this reason, with adequate drainage, open permeable soils can be irrigated more safely with lower quality water than tighter soils.

FREQUENCY OF IRRIGATION

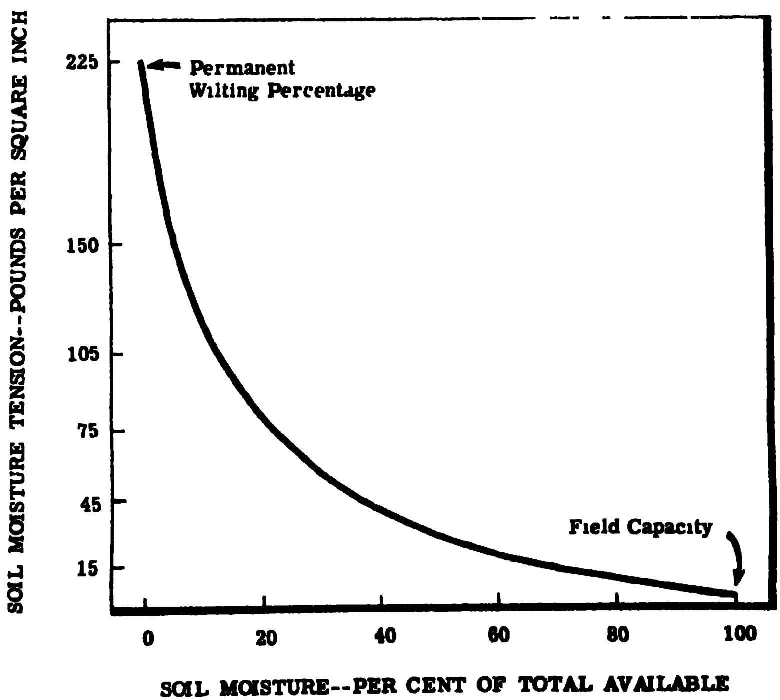
Soil holds moisture with considerable force. The drier a soil becomes, the tighter the water is held. Only free water drains out of soils. Its movement is controlled by gravity. Water remaining in soil after all free water has been removed is held by the soil. This water is

held by a force of five pounds or more per square inch. At this point soil moisture is said to be at "field capacity." It has no free water. It also has all the capillary moisture it can hold.

As the soil becomes drier, the force of attraction between soil and water increases. As this force increases, it becomes more difficult for plant roots to extract the water. When plants can no longer draw moisture from the soil, the soil is at the permanent wilting percentage. The remaining water is held to the soil by a force of 225 pounds per square inch. This force is greater than the pulling force exerted by plant roots.

A great deal of energy is required to move water from soil into plants. The amount of energy is greater than the attraction between the soil and water. For example, at field capacity it requires energy from the plant equal to five pounds pressure per square inch to extract water. As the amount of capillary water declines, that remain-

Figure 22-1. Soil moisture remaining in the soil of various moisture tensions (Fly Creek clay loam).



ing is held more firmly by the soil. More energy is required by the plant to extract it. Thus, 45 times as much energy is required at the wilting percentage as at field capacity. As the amount of capillary water declines, the task of plant roots becomes increasingly greater. This task of the plant continues to increase until the wilting point is reached.

When energy required by plants to obtain water becomes too great, growth is reduced. The force with which moisture is held to soil does not increase very rapidly until about 60 to 80 per cent of the total available moisture has been removed. When soil contains less than about 30 per cent of its total available water, plant growth declines. That means irrigation water should be applied before the level of available water drops below this point.

WHAT IS A DROUGHT?

Agricultural drought a condition of rainfall deficiency with respect to crop production - has not been defined accurately. It should be defined on the basis of soil moisture conditions and resultant plant behavior. This method of defining drought is more practical than using rainfall records.

Just when a period of relatively dry weather becomes a drought is a matter of debate. The effects of droughts of varying duration and intensity are known only in a general way. It is this relationship between drought duration and intensity that holds the key. It is the period of time being considered and the amount of rainfall received during this period.

We may be safe in assuming that a drought begins at the soil moisture level where plant roots begin experiencing difficulty in getting moisture from the soil: that is, at the time when plant growth begins to slow down because of lack of moisture. This point is reached when from 60 to 70 per cent of the capillary water has been used by plants. At this point plant growth begins slowing down. After all, it is plants, not man, that determine when droughts set in. Droughts begin when the capillary water level falls low enough to keep plants from getting their full quota of water.

Crops need definite amounts of water during their growth period. The amount of water needed usually increases as crops grow older or become more mature. Soils can hold only so much capillary water at any one time. Consequently, the faster plants remove capillary moisture, the quicker the soil's supply is exhausted. Older plants use

water faster than young ones. Because of this, there is need for more frequent rains during periods of heavy use of soil moisture. If the rainfall pattern is not adequate to meet this demand, the difference should be added as irrigation water.

If we are to determine when droughts set in and how much irrigation water is needed, we need to know three things. First, we must know how much available water soils will hold—what their storage capacities are. Second, we must know at what rate plants use water at various stages of growth or, more particularly, what the daily evapotranspiration rate is for each month of the crop growing season. Third, we must know what our chances are of getting enough rainfall at each successive stage of crop growth.

By knowing how much available water a soil will hold, we know how much water can be stored for the growth of crops By knowing how much of this supply is used daily, we know how long it will last. By knowing the probability of having the supply replenished by rain, we know how much of an irrigation problem we have or how much water needs to be added artificially to keep crops growing at top speed.

We also need to know what portion of the rainfall is likely to be lost as runoff—or, better, how much of it will seep into the ground.

The frequency of drought may be estimated for a particular crop. This may be done by determining the number of days during the crop's growing season that soil moisture tension exceeds a point known to slow crop growth appreciably. Soil moisture tension is the attraction of soil grains for water. As the tension rises, it becomes more difficult for plant roots to get water.

In other words, the frequency of drought may be estimated by determining the number of days during their growing season that crop plants find it difficult to get enough moisture to keep them growing at top speed. That is the number of days there is competition between plant roots and soil for moisture. Those days in which plants do not get enough moisture we call drought days.

The frequency of drought days depends on a number of factors. They include rainfall pattern, moisture characteristics of the soil, depth of rooting, reaction of the plant to moisture tension, and rate of evapotranspiration.

Drought, thus determined, has a truly agronomic character. It is a yardstick for measuring adequacy of climate and soil for providing the best soil moisture conditions.

Past rainfall records and an estimate of evapotranspiration can be used in determining drought frequency.

WHEN TO IRRIGATE IN HUMID AREAS

One of the problems associated with irrigation in the humid area is that of determining when to start irrigating a crop.

The object of irrigation is to keep the tension of the soil water from getting high enough to depress plant growth and yield. This value is unknown for most crops. One of the more important problems of irrigation is to determine soil moisture conditions at any given time. This is simplified by the fact that, for a given soil, the value of the soil moisture tension is related to the soil moisture content. This relationship is known as the moisture characteristic of the soil, or the difficulty plant roots have in getting moisture from the soil.

The time at which the soil moisture supply has been reduced to a danger point must be determined. It can be determined by measuring either the tension or moisture percentage.

EVAPOTRANSPIRATION METHOD

The status of soil moisture at any given time can be determined indirectly by accounting for differences between water added to and water lost from the soil. On drained land water is lost by evaporation from the land surface and by transpiration of the vegetative cover. The combined process, known as evapotranspiration, accounts for all water lost. Irrigation and rainfall minus runoff accounts for all water added.

We set up a simple bank account procedure to determine the readily available moisture supply in soil at any given time. This is done by keeping a record of water added to the soil and the amount lost daily by evapotranspiration. When this supply is reduced to zero, or near zero, the need for irrigation is indicated.

Actual and calculated evapotranspiration rates. Actual evapotranspiration rates are in close agreement with the ones developed by more elaborate methods. There is close agreement between measured and calculated rates of evapotranspiration. Neither is there a great difference between computations based on long-term averages of temperature and computations based on actual occurring tempera-

ture. This has practical significance. It is easier to use average figures determined in advance than to work with current data.

Method of application. The usefulness of this method can be illustrated by using a field of tobacco. The tobacco was growing on Ruston coarse sandy loam at Raleigh, North Carolina, in July. The moisture characteristics of Ruston coarse sandy loam show that at field capacity its moisture content is 12.5 per cent. This represents 1.5 inches of water in the root zone.

The daily evapotranspiration for the Raleigh area is 0.21 inch in July. Therefore, by subtracting evapotranspiration and adding rainfall and irrigation to the supply, a running record of available soil moisture can be kept. This is illustrated in Table 30.

TABLE 30

EXAMPLES OF SOIL MOISTURE ACCOUNT
RUSTON COARSE SANDY LOAM

Volume weight: 1.55	
Moisture content (weight basis) at field capacity.	12.5 per cent
Moisture content at maximum allowable tension equals:	4.4 per cent
Useful moisture range	8.1 per cent
Volume of water in useful range (12 inches of soil): 1.5 inches	

Date	*Evapotranspiration*	*Precipitation*	*Irrigation*	*Supply*
July 1	0.21	1.80	...	1.50
2	0.21	...	....	1.29
3	0.21	....	...	1.08
4	0.21	...	....	0.87
5	0.21	0.26	..	0.92
6	0.21	...	...	0.71
7	0.21	....	....	0.50
8	0.21	..	...	0.29
9	0.21	...	...	0.08
10	0.21	...	1.50	1.37
11	0.21	..	...	1.16
12	0.21	1.06	....	1.50

When a need for irrigation is indicated, as on July 10 in Table 30, 1.5 inches should be applied. Rainfall is also added to the supply, except when the total exceeds 1.5 inches. If 1.5 inches are exceeded, the additional water is not added to the supply because it becomes unavailable to the plants. It passes below the root zone to the water table.

A number of factors need to be known to use the evapotranspiration approach. They are the rooting depth of the crop, moisture

characteristics of the soil, the moisture tension tolerance of the crop, evapotranspiration rates, and rainfall records.

Results of application. In 1951, 1952, and 1953 irrigation was scheduled on the basis of this method. Both the yield and quality of flue-cured tobacco was improved at Oxford, North Carolina, over a three-year period. In all three years important yield increases were obtained. This method made it possible to keep the moisture level from falling below the danger point. Moisture conditions were kept favorable for rapid growth all season. The result was a larger yield and a higher quality product.

EROSION CONTROL ON IRRIGATED LAND

Irrigation is often a destructive type of agriculture. Water flowing in streams on bare land is very erosive. When flowing water is applied to steep slopes, it is even more destructive. Figure 22-2 shows the critical, or maximum, allowable furrow stream for different slopes. Two of the curves were developed by observing the effect of different sizes of furrow streams under actual field conditions. The third was developed from results of tests with one soil under laboratory conditions.

The curves show serious erosion results on the steeper slopes, with a small increase in flow above the critical-size stream. If the furrow has a slope less than 1.0 per cent, the addition of five gallons more per minute per furrow may have little or no harmful effect. If the slope is less than 0.5 per cent, the addition of ten or more gallons per minute may be harmless. As the slope increases, however, the size of the furrow stream must be accurately adjusted. With a 5 per cent slope and a critical furrow stream of two and a half gallons per minute, a small increase to the stream of one half or one gallon per minute may cause serious soil movement.

These data emphasize the importance of maintaining flat grades for surface irrigation. Land leveling should be used to shape the slope of the land where practical. If it is not practical to level the land, farming operations should be conducted across the slope. They should be almost on the contour.

Such practices reduce erosion and decrease the time for irrigating such land. Less water needs to be run over flatter grades to get the desired amount of water into the soil. Water can go into the soil only so fast. The more rapidly it flows, the less enters the soil. Then more water needs to be run over the soil for irrigation.

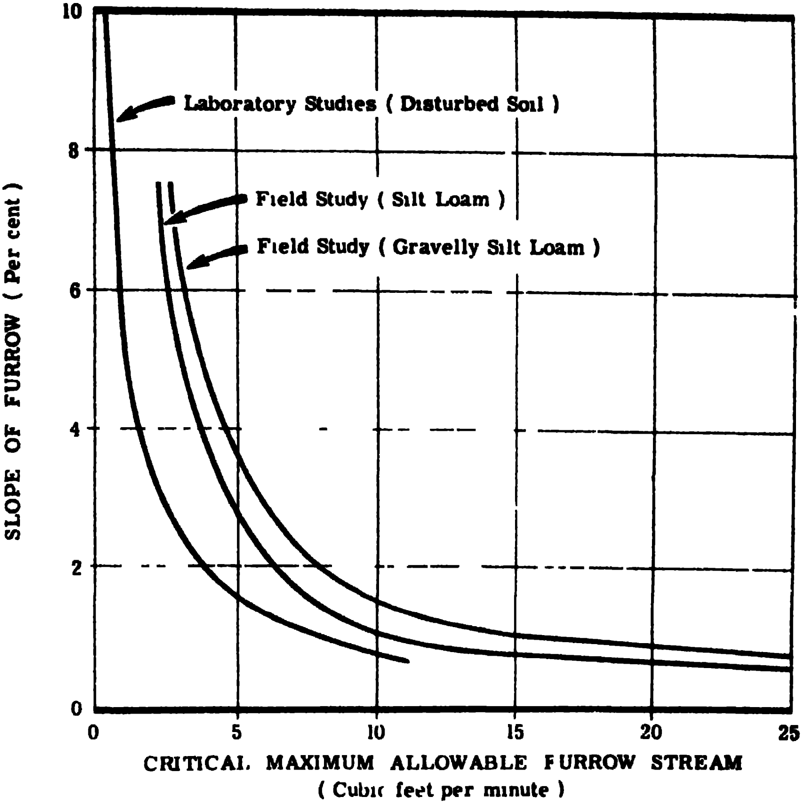


Figure 22-2. Critical-size furrow stream for different slopes on three soils.

Thus, it can readily be seen why erosion is difficult to prevent on steep lands when they are irrigated by surface methods. Safe handling of water on the steeper grades requires control of the stream size. The runs should be short enough to reduce stream force. Siphons, a gaited surface pipe, gaited wooden flumes, gaited spiles, and other devices have been developed to control the size of furrow streams. Although these controls are relatively new, farmers in certain irrigated areas are beginning to use many of them. Elsewhere, the advance in handling irrigation water has been slower. It is not uncommon in these areas for 25 tons of soil per acre to be removed from a field during an irrigation. Application of twice the critical stream to a furrow in an Idaho bean field removed one-half inch of topsoil in one irrigation.

Efficient use of irrigation water is almost impossible on steep fields. This is particularly true if the furrows run down the slope. The production of row crops on steep slopes results in very poor moisture distribution. This is true even with careful irrigation, short runs, and medium size streams. Furrow irrigation gives a poor distribution of water. Even on relatively flat land, the upper part of the field receives a little more irrigation than the lower part.

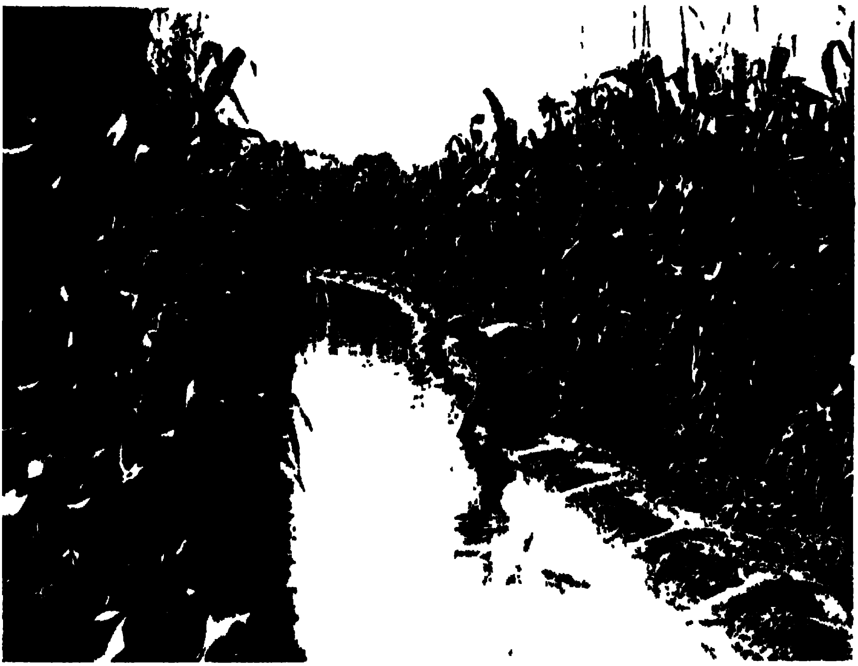


Figure 22-3. Siphon tubes are used by this Nebraska farmer to get water from the irrigation ditch into the corn middles. This is one of the several methods of applying irrigation water. (Soil Conservation Service Photo)

On steeper land, however, this difference is so great that the upper end generally has enough moisture before the lower part of the slope has received any. At the time the water is turned off, the upper part of the field usually is wetted too deeply and the lower end is not wetted deeply enough.

Shortening the length of the run helps to reduce this difference.

The difference persists even on very short runs when the slopes are steep. The upper end of a 127-foot run on a 16 per cent slope absorbed 2.2 inches of water. Only 1.2 inches went into the ground 75 feet farther down the slope. On the lower part of the slope the water did not fill the root zone. The penetration at the upper location was deeper than four feet.

The beet yield was 30 tons per acre on the upper half of this field. However, it was only 21.7 tons on the lower half. Corn produced 58 bushels on the top half and 31 bushels on the lower half. The soil was more fertile at the foot of the slope than at the top. Consequently, the difference in yield was even greater than indicated.

Soil moisture distribution on steep slopes can be improved by reducing the grade of irrigation furrows. Reducing the grade on one field from 16 to 3 per cent, by directing the furrows across the slope, reduced the rate of soil loss from thirteen tons to one ton per acre per year. The amount of water added to the root zone at the upper part of this field was 2.4 inches per irrigation. Just 150 feet down the furrow the amount was 2.02 inches. The crops were more uniform and the average production was higher. Corn yielded 69 bushels per acre on the flatter slopes. The yield on the steep slope was 45 bushels.

Water entered the soil twice as fast on the flat slopes as on the steep slope. The same amount of water was put into the soil in twelve hours with the furrows on a 3 per cent grade that entered the soil in twenty-four hours when the furrows were directed down the 16 per cent slope.

There was also considerable reduction in the amount of irrigation waste water. Most irrigations permit a certain size stream of irrigation waste water at the end of the furrow. The shorter period required for irrigation reduced the volume of water lost as irrigation waste.

To irrigate "across the slope" is not without its disadvantages. It requires more careful layout of furrows. The first irrigations require more careful attention and the water necessarily will have to be moved more often. This results in more efficient irrigation and higher yields, however.

QUESTIONS

1. Discuss briefly the history of irrigation.
2. What marks the beginning of modern irrigation in this country?

3. How does irrigation affect our food supply? Why is this so necessary?
4. How is irrigation used in the East?
5. What do we mean by consumptive use of water? What does it include? What is its relation to irrigation?
6. How is consumptive use of water expressed?
7. Name some of the most important factors affecting consumptive use of water.
8. How does water quality affect irrigation?
9. What is a saline soil? How is it developed?
10. How is the salinity problem handled?
11. Why is drainage usually a problem on irrigated land in the West? Does the same problem exist in the East?
12. What determines when irrigation water should be applied?
13. What do we mean by drought?
14. What is meant by frequency of drought? How is it estimated?
15. How do we determine when to irrigate in the humid area?

23

Soil Drainage

DRAINAGE, the removal of free soil water, is essential for good soil management. Use of some of the most productive land in the United States is dependent on drainage.

Topography and soil type are important factors affecting the distribution of undrained land areas. High-value cash crops are produced on well-drained land throughout the country. Open ditches and tile drains are both used extensively. Open ditch drainage is most generally used in the production of sugar cane and other crops grown on flood plains and muck soils.

The most extensively drained area is found in the Corn Belt. The Corn Belt has relatively uniform climatic conditions, topography, soil type, crops, and type of farming. Here drainage is of special importance in soil management.

The purpose of drainage is to remove excess water, which fills soil pores and excludes air. The absence of oxygen in turn prevents processes that make food available to plants. The removal of water, on the other hand, improves aeration and favors decomposition and other processes that make the soil healthy. In this way drainage leads to the production of bumper crops on otherwise wet soils. All of the knowledge of soil management and the experience gained by farmers must be utilized if top yields are to be obtained from any given field year after year.

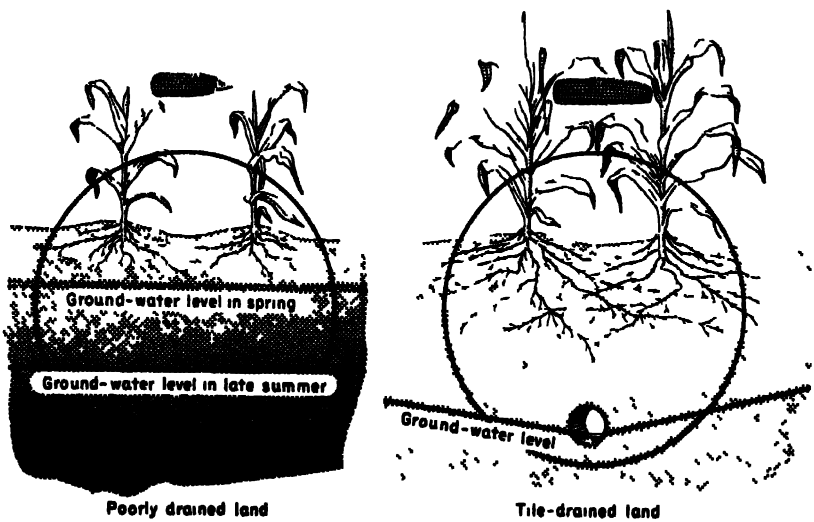
BENEFITS OF DRAINAGE

There is a good deal of evidence showing that drainage has many beneficial effects. These effects show up when drains are installed in

soils where excess water occurs any time during the growing season. Some of the benefits of drainage are (1) It permits aeration of the soil. Aeration is essential to root extension and growth. (2) It makes conditions favorable for the development of beneficial soil microorganisms. As the free water is removed from the soil, air moves in. Aeration is as important as suitable moisture conditions to the growth of microorganisms. Microorganisms, in turn, make plant food available. (3) Drainage increases yields and improves the quality of the crops. (4) Drainage permits earlier planting. This increases the length of the growing season. (5) It increases the root feeding area. This permits greater development of root systems. Greater development of root systems means more economical use of available water and plant food. (6) Drainage may make available for cultivation highly productive acres which were not previously suited.

Let us follow the seasonal sequence of events on a typical Corn Belt farm. In this way the importance of drainage can be better un-

Figure 23-1. Roots of plants growing on wet soil are restricted to a shallow layer of soil at the surface in the spring. This reduces both the feeding range and the amount of food available to the plant roots. In addition, when the ground dries out later in the season the shallow root system exposes the plants to damage by drought. (Soil Conservation Service Photo)



derstood. Practically every operation on the farm is influenced by the amount of water in the soil. The time of plowing, the number and kind of seedbed operations, the date of planting, and the number of cultivations are all largely determined by conditions of soil tilth as affected by improper drainage. Even harvests are frequently made more difficult because of poor drainage.

Legumes and grasses are likely to heave badly on soils that are wet during the winter. This frequently reduces the amount of vegetable matter available for soil improvement in the spring. The soil will be more difficult to manage because of the reduced amount of plant growth. Heavy crop growth serves as a support for the farm tractor and lessens soil compaction. Because of the poor plant growth associated with a wet field, the field is likely to be plowed in the fall. Fall plowing leads to further soil structure breakdown.

Or the land is likely to be plowed late in the spring—too late for a good crop of corn. Difficulties do not end with late plowing Because of the poor sod and generally wet condition, the plowed field is likely to be cloddy—so cloddy that the hot sun and winds of early summer rapidly dry the surface soil. Surface moisture falls to such a low level that kernels of corn planted in the dry soil do not germinate promptly. They do not germinate until the necessary moisture is supplied by rain. The hazards of producing the crop are increased before the corn sprouts.

If the farmer is to plant corn in a cloddy field, he must reduce the clods to fine powder. He then proceeds with his planting operations. This pulverized seedbed is again hazardous. Rains compact the surface of the soil more easily. The ground is crusted and sealed. The surface crust interferes with young corn and slows the movement of water through the soil. In addition to these unfavorable mechanical conditions, soil aeration is also reduced. The soil warms up more slowly. Young corn plants growing on poorly drained soil frequently turn yellow within 24 hours.

In a wet field like this cultivation will be difficult if not impossible. Environments are more favorable for weed growth than for corn. Consequently, the corn suffers from weed competition. In addition, the stunted root system is unable to supply the growing plant with subsoil moisture as the season advances. This has led to the paradoxical statement that certain Corn Belt soils are droughty because they are too wet. The corn plants suffer from drought late in the season because they had too much water earlier.

Drainage problems in New England are less severe than in the

Corn Belt because of the more sandy soils. According to the drainage census, only one cultivated acre out of fifty in New England needs drainage. In contrast, the same census shows that one cultivated acre out of every three in Ohio requires drainage.

DRAINAGE NOT INJURIOUS TO LAND

Research has shown farm drainage to be a valuable practice. It makes possible soil and crop management programs that better conserve and improve farmland. It also makes better use of the water that falls on the farm. All in all, good farm drainage is a sound investment. It pays the farmer substantial dividends in the form of increased yields and better land utilization.

There are no experimental data to support claims, made by some, that farm drainage is exhausting ground water supplies, changing the pattern of rain and snowfall, causing excessive floods or droughts, lowering the productivity of the soil, causing an increase in insect populations, or stripping the top fertile soil from the land. On the other hand, there is much experimental evidence to show that properly installed drainage systems increase crop yields and make proper soil management possible.

Tile drainage was first practiced in the United States in 1835. After the Civil War the invention of the dredge, to dig ditches, made for a rapid stride in land drainage. It is now estimated that about 80 million acres of our most productive land are associated with drainage enterprises.

Farmers in Europe and Asia have been improving their land by drainage for many centuries. With but few exceptions, the low, wet lands on the farm, when properly drained, can be classed with the most fertile and productive acres. For instance, Webster soils, which are common to a number of Corn Belt states, when properly drained are rated as the number one corn land.

THE WATER PROBLEM

Whenever there is a drought period, whether it is for weeks or for years, farm drainage is often blamed for lowering the ground water table to exaggerated depths. Some critics even claim that drainage causes droughts.

Geologists report that for the country as a whole there is no progressive decline in the water table. Serious local water shortages

may be aggravated by pumping the water from the ground. Shortages are also aggravated by pumping water for irrigation, cooling, industrial needs, or municipal purposes. Ground water is removed at a rate greater than the sources can normally replenish it through natural soil flow.

The need for more water on farms, plus the ease with which water now can be pumped, has increased its per capita consumption. This consumption has been increased about four times in the past thirty years. Many farm wells located in low-yielding water strata are said to be going dry. Actually, the well cannot yield the water fast enough to meet the increased demand. We must remember that shallow wells are often affected by prolonged wet and dry periods.

THEORY OF FARM DRAINAGE

The purpose of drainage is to remove excess water from the root zone as quickly as possible. This results in increased yields and improved quality of the crops.

It has been found that, for cultivated crops, the water table should be at least one foot below the surface. For grass crops, it may be a little shallower.

There are three kinds of soil water:

1. *Hygroscopic:* water held so tightly as a thin film around soil particles that the plants cannot extract it.
2. *Capillary:* water loosely held around soil particles by capillary attraction. This film supplies needed water and nutrients for plant growth.
3. *Gravitational:* excess or free water. Free water is removed under the force of gravity. Free water fills the openings between the soil particles not occupied by the two other kinds of soil water. On poorly drained soils the removal of gravitational water is so slow that water becomes harmful to plant roots. Gravitational water collects like free water in an open hole.

Agriculturally speaking, the ground water table is the distance from the surface of the ground to the water surface in an open hole. The ground water table ranges from the ground level to a depth of about ten feet. This water near the ground surface has little relation to deep ground water levels. It is referred to as the "perched" water table. The perched water table is usually separated from the deeper layers of water by impervious or slowly pervious subsoils.

Artificial drainage removes only free or surplus water. Drainage

does not disturb or reduce useful capillary water, which is essential to plant growth. Free water, on the other hand, only removes and excludes air, which is so essential to root development. A mineral soil suited to agriculture cannot be overdrained because of this. During a drought, a tile-drained soil may actually produce better crops than a similar soil not so drained. Tile and open ditch drains promptly remove excess water. This enables crops to develop healthy and vigorous root systems. On poorly drained soil the development of roots may be restricted by surplus water during wet periods.

A completely saturated fine-textured soil may contain the equivalent of six inches of water per foot depth of soil. In some cases not more than one inch of this is gravitational water—water that can be removed by drainage. Thus, one inch of rain may cause a perched water table to rise about one foot. This is particularly true when water falls on a heavy soil carrying moisture up to the capillary capacity.

The lateral or sidewise movement of water through the soil is relatively slow. Because of this, the beneficial range of tile lines or open ditches seldom exceeds 50 to 100 feet on either side of the

Figure 23-2. *Open ditch drains are used to draw off surface water rapidly. This open ditch drain in Louisiana is well sodded to prevent erosion.* (Soil Conservation Service Photo)

drain Capillary water movement tends to be vertical but is usually slow For this reason, capillary water cannot supply plants with any considerable amount of moisture from the free water table Crops are almost entirely dependent on the capillary water of the root zone

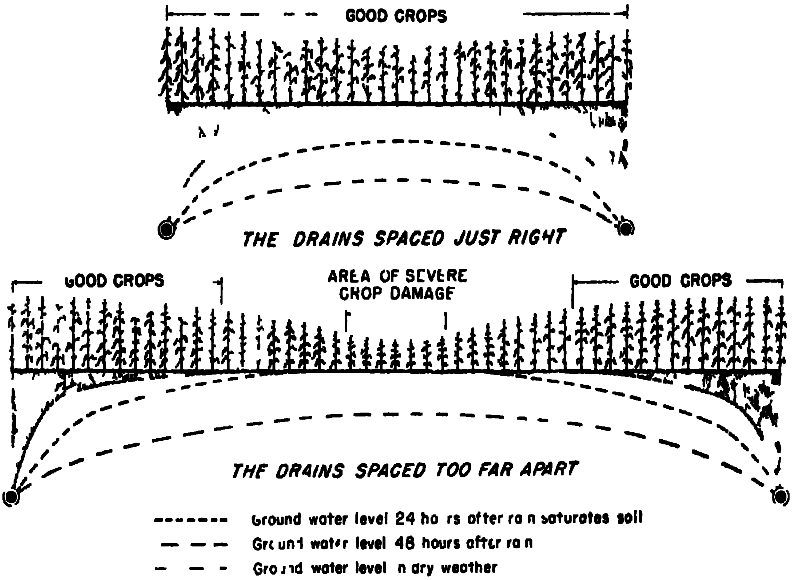


Figure 23 3 How spacing of tile drains affects ground water level and crop damage (Soil Conservation Service Photo)

DRAINAGE AND GROUND WATER LEVELS

The Minnesota Agricultural Experiment Station studied ground water elevations relative to farm drainage for more than thirty years These investigations show that perched ground water tables can be lowered on drained areas at the rate of about one foot in 24 hours It requires some three to four days to lower the water table to the tile depths On the other hand, on undrained areas, free water in soil recedes at a much slower rate

In this case, a rainless period of several weeks may be required to cause a water table drop equal to that on the drained area Thereafter, if no precipitation falls, the ground water table recedes below tile level at the same rate on drained and undrained land This rate

of drop below the tile depth may range from one to several inches per week during drought periods. At these deeper soil depths the loss of water by evaporation and transpiration is slow. During the spring months precipitation is generally sufficient to bring the perched water table on poorly drained lands back near the ground surface. There is no indication that farm drainage materially alters runoff. Neither does it affect the storage capacity of the better agricultural soils; nor does it have significant effect on the deep ground water.

DRAINAGE IMPORTANT TO PROPER SOIL MANAGEMENT

Besides improving the soil moisture conditions in the root zone, farm drainage is important to good soil management. The resulting increased yields from flat, wet areas, may be sufficient to meet farm needs. Then some of the sloping land can be planted to appropriate soil protecting crops. The high yield from one acre of flat land, when properly drained, may equal that from several acres of sloping land. This may make it possible to return much of the sloping land to grass and trees.

In many sections of the country nearly every farm has a drainage problem. Soil Conservation Service studies indicate that a high percentage of the farms in the humid area have drainage problems. The most productive lands are flat. Flat lands are most apt to be wet. If they are drained, crop yields rise and total farm production increases. In many cases, drainage is necessary before a sound crop and soil management program can be adopted. There can be little soil improvement of undrained, wet lands.

RUNOFF STUDIES

Rain and snow are disposed of by surface runoff, subsurface runoff, evaporation, transpiration, and deep seepage. If agricultural drainage appreciably decreased, deep seepage runoff from drained areas would be greater than before drainage.

A study made by the University of Minnesota indicated that drainage did not affect deep seepage appreciably. The study included 10 million acres in the Des Moines River watershed and 2 million acres in the Iowa River watershed. The drainage operations

on these watersheds included the installation of tile drains and open ditches and some straightening of stream channels.

One-third of the total area of both watersheds was drained. In the Des Moines watershed there was one unit of 4 million acres that received 67 percent of complete drainage. Another unit of 2,700,000 acres was completely drained. The monthly precipitation for this study ranged from 0.88 to 9.96 inches.

It was concluded that during flood periods there was no important change in the behavior of these two streams due to drainage The total runoff from storms of like precipitation, the maximum rates of discharge, and the rainwater storage conditions within the basins were not altered by excessive drainage.

This research definitely indicates that the drainage of a large area of farmland does not seriously affect the water storage rate of the area. There are a few exceptions, like isolated swamps, ponds, or small lakes. These are so perched on or near porous soils that they may greatly affect the surrounding ground water. Likewise, drainageways installed near open bodies of water can lower the level of the water if the surrounding soil is porous.

Not all wet land should be drained since this process is expensive. The benefits must be carefully weighed against the cost. If there is any question about the productivity of the soil, the best procedure for testing the soil should be followed. It is wise to get the best information available to evaluate the problem.

DRAINAGE OF IRRIGATED LANDS

Irrigation and drainage are inseparable. Lands long irrigated must also be drained either naturally or artificially. In irrigation practice, it is impractical to apply just the proper quantity of irrigation water without getting some excess.

In fact, some excess is often necessary. The excess in these cases insures the continued productivity of irrigated land. This flushes the root zone and leaches soluble salts. Thus, in irrigated lands drainage may be defined as "the removal of excess water and soluble salts from soil." If an area is to remain productive, it is necessary that the quantity of salts removed by drainage should equal or exceed the quantity brought into the area in irrigation water.

Waterlogging and the attendant effects of salinity and alkalinity are injurious. They constitute the greatest threat to the continued

productivity and prosperity of an irrigated region. The solution of drainage problems is most important if irrigation agriculture is to be perpetual.

Extensive areas of some of the most fertile soils in the West have been abandoned because of inadequate drainage. There are 21 million irrigated acres in the 17 Western States. Their productive capacity may have been reduced as much as 20 per cent by waterlogging and attendant factors. The loss in crop production from these causes was estimated to exceed $100,000,000 annually.

DRAINAGE IMPROVES YIELDS

The yield of both sugar cane and sugar was increased substantially in Louisiana by drainage. On 105.6 acres of experimental land, the yields of both cane and sugar were increased. The cane yield was increased 5.84 tons per acre. The yield of sugar was increased 1,267 pounds per acre.

The most responsive test area of 47.2 acres averaged 52.49 tons of plant cane per acre and 38.74 tons of first-year stubble cane. This was an average yield of 45.61 tons per acre for the two crops. The remaining 1,231 acres of the test plantation averaged 25.42 tons per acre over the same two-year period.

The drainage operation consisted of grading the cuts– areas between open drainage ditches. The earth along the lateral ditches was graded toward the center of the cut. Earth from the center of the cut was sloped toward the lateral ditches. The cut was crowned like a highway. Drainage within the cut consisted mainly of the depressions made between the rows by the tractor wheels.

Maximum yields were obtained with 13 inches of crown per 100 feet. The precision of grading caused a definite bearing on yield. Elimination of pockets two inches deep or over increased the yield of plant cane 7 and first-stubble cane 3.5 tons per acre.

By doubling the width of cuts to accommodate 26 rows of cane instead of 13 and grading this wider cut, the yield of cane was increased 7.01 tons per acre. The area occupied by the eliminated ditches was returned to cultivation. The increased yield was worth $49.00 per acre. The grading cost was only $25.00.

A summary of 67 farms in four counties on the Eastern Shore of Maryland showed that drainage increased crop yields greatly. The average corn yield on 17 farms in Caroline County increased from

19.6 bushels per acre to 42.9 bushels after draining. On 23 farms in Queen Annes County the increase was from 11 to 33.9 bushels, and on 24 farms in Somerset County the corn yield was raised from 30 to 50.4 bushels per acre. The effect of drainage on the yield of corn, wheat, and hay is shown in Table 31.

TABLE 31

EFFECT OF DRAINAGE ON CROP YIELD

Crop	*Caroline County* (bushels)	*Queen Annes County* (bushels)	*Somerset County* (bushels)
Corn:			
Before drainage	19.6	11.0	30.0
After drainage	42.9	38.9	50.0
Wheat			
Before drainage	10.9	8.3	15.0
After drainage	23.0	20.8	25.0
Hay:*			
Before drainage	0.54	0.42	1.5
After drainage	1.80	1.56	3.2

* Yields expressed in tons per acre.

The average wheat yield more than doubled on all farms included in the survey. It increased from 11.2 to 22.7 bushels per acre. The average hay yield on 64 farms increased from 0.84 to 2.25 tons per acre as a result of drainage.

Yields on three additional farms in Kent County, where 315 acres were drained, were improved substantially. Corn increased from 24.3 to 46.1 bushels per acre. Wheat increased from 14.3 to 24.9 bushels and hay from 0.87 to 1.51 tons.

Substantial increases in crop yields resulting from drainage have been reported in other states. In every case, the returns from increased crop yields the first year after drainage more than paid for installing the drainage system.

PERMEABILITY AND DRAINAGE

Soil permeability is the capacity of the soil to transmit water and air. It is measured in terms of percolation. Percolation is the rate of flow of water through a unit cross-section of soil in unit time. Permeability may be judged by examining the visible soil characteristics.

A knowledge of the rate of movement of water through each different soil horizon is important. The amount of water a soil can

transmit during a single rain or succession of rains is governed by the permeability of the soil. Permeability in this case includes the infiltration rate: that is, how fast the water gets into the soil. Runoff is regulated by the rate at which water enters surface soil and percolates to lower depths. In other words, soils that take and transmit

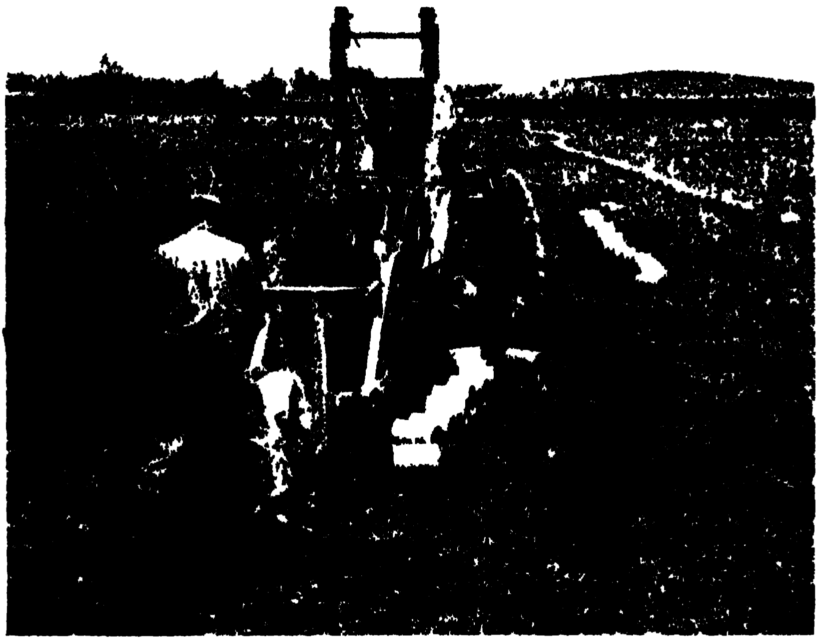


Figure 23-4. Tiles are used to drain soil where open ditches are objectionable. A tile drainage system is being installed on this Iowa farm. (Soil Conservation Service Photo)

water slowly produce high runoff during hard or prolonged rains. Thus, permeability and infiltration data are valuable in planning a drainage program.

Knowledge of soil permeability is necessary to the sound planning of drainage measures. For example, a tile system may not be practical on slowly permeable soils. Open ditches may be needed to handle the excess surface water on these soils. Where percolation rates range from moderately slow to moderate, a tile system will function

properly. The thickness of each horizon and its percolation rate must be considered in determining the size, depth, and spacing of tile.

Soil texture is generally considered the most significant factor in evaluating permeability. Other factors are considered, but they are of minor importance.

A system has been developed for classifying soil permeability from a nationwide standpoint. It consists of the seven permeability classes shown in Table 32.

TABLE 32

PERMEABILITY CLASSIFICATION OF SOIL

Permeability Class	*Permeability Index*	*Percolation Rate in Inches per Hour Through Saturated, Undisturbed Cores Under ½ Inch Head of Water*
Very slow	1	Less than 0.05
Slow	2	0.05 to 0.2
Moderately slow	3	0.2 to 0.8
Moderate	4	0.8 to 2.5
Moderately rapid	5	2.5 to 5.0
Rapid	6	5.0 to 10.0
Very rapid	7	More than 10.0

C. H. M. van Bavel of the Iowa State College described a method developed to determine the permeability of the soil. The method can be used by almost anyone. It is a guide to tell whether or not a soil can be drained and, if so, how well it will drain. The method is simple and requires little equipment.

Water table near surface. The method recognizes that areas in need of drainage have water tables one foot or less from the surface during wet seasons. The equipment needed is a post hole digger eight inches in diameter, a four foot rule divided into feet, a watch, a pitcher pump with a hose, and some small sharply pointed sticks about two inches long.

A four foot hole is dug with the digger. Water immediately starts filling the hole and eventually rises as high as the water table in the soil. Usually, this filling takes less than a day.

When the water in the hole reaches its maximum height, it must be within one foot of the surface. Then the permeability of the soil can be measured. Start early in the day. Place a small stick in the side of the hole exactly one foot below the surface of the water. Use a rule to locate this stick or marker accurately. After placing the

marker, empty the hole as rapidly as possible. Use a hand pump if available. If no pump is available, a scoop made of a tin can on a stick can be used. But this is not an ideal substitute because it is slow and it is hard to get the last of the water out this way.

Now observe the length of time necessary for water to rise to the marker placed in the side of the hole one foot below the original water surface. The permeability of the soil can then be read from Table 33.

TABLE 33

SOIL PERMEABILITY

MEASURED BY THE LENGTH OF TIME REQUIRED TO FILL THE AUGER HOLE UP TO ONE FOOT BELOW THE WATER TABLE

Time (hours)	*Soil Permeability* (feet per day)	
1	1.64	
1.5	1.41	Rapid
2	0.82	
2.5	0.66	
3	0.55	Moderate
3.5	0.47	
4	0.41	
4.5	0.37	
5	0.33	Slow
5.5	0.30	
6	0.27	
6.5	0.25	
7	0.23	Very slow
7.5	0.22	
8	0.21	

Suppose two fields are examined. One is drained with tiles four feet deep and 100 feet apart. The other is undrained. If the soil permeability is about the same on both fields, say 0.6 foot per day, a four-foot depth and 100 foot spacing will be satisfactory on the undrained field too. This method therefore provides a sound basis for the comparison of soils.

Sample several locations. Soil permeability, like any soil property, is variable from place to place. Measurements should be made at several representative locations in a field to get the average picture. The measurements should be made on the same kind of soil. If available, a soil map will help. One measurement for every acre or two should be enough to obtain a satisfactory estimate. However, the more test holes dug, the more reliable the permeability estimate.

Where a drainage system is not available for checking, the infor-

mation can still be obtained by dividing the soil into groups on the basis of permeability. The four classes are (1) rapid, (2) moderate, (3) slow, and (4) very slow. Rapidly draining soils have permeabilities of more than 0.70 foot per day. Laterals four feet deep can be spaced far apart, possibly 120 feet or more on such soils.

If the soil permeability is between 0.70 and 0.45 foot per day, the soil drains moderately. Laterals should be spaced between 80 and 120 feet, depending on the situation.

Slowly draining soils have permeabilities between 0.45 and 0.29 foot per day. Laterals on these soils may need to be placed as close as 50 feet.

Soils with permeabilities less than 0.29 foot per day drain very slowly. These soils, in all probability, cannot be drained economically.

The depth of the tile should also be considered in relation to the presence of hardpan and gravelly layers. Slope and outlet possibilities are also important, but spacing of the laterals is a major factor in drainage costs.

Exercise

1. Follow the instructions outlined in the section in this chapter headed Water Table near Surface. Determine the permeability of the soil on a poorly drained area.

Questions

1. What do we mean by drainage?
2. Name and describe the three kinds of water in soil. Which kind does a plant use?
3. How does drainage affect the amount of water available for plants?
4. What are the chief beneficial effects of drainage?
5. How does drainage affect available water supply during droughts?
6. What do we mean by the water table? Describe a simple method of determining the water table of a particular area.
7. Why is drainage important to proper soil management?
8. Why is drainage so necessary on irrigated lands?
9. How does drainage improve crop yields?
10. What is soil permeability? How does it affect drainage? What determines permeability?

24

Watershed Management

WE have known for a long time that an intimate relationship exists between land and water. We have also known that the method of managing land affects runoff and stream flow. Even ancient Greece recognized this relationship and attempted to measure it.

With the passage of time our interest in the effect of land use on water has increased. This is shown by our growing interest in floods, water storage, and their associated difficulties. Out of this interest the principles of present land conservation have come.

More recently, this interest gave birth to the idea of watershed management. The main purpose of watershed management is to apply these principles to drainage basins. Most people realize that this is needed. But few understand the relationship among plants, soil, and water that controls runoff and stream flow.

Efforts to control floods in this country began with the earliest French settlement. It started on flood plains of the Mississippi. The first levee was constructed at New Orleans in 1717. In the beginning each landowner along the river built his own levee. Later on, the construction of levees became a public responsibility. People living several miles back from the river were required to work on levees and local governments supervised the work.

However, the government of the United States was slow to become interested in flood problems. The first interest was shown about 1824 when the Army Engineers were authorized to begin work on navigation improvement. About twenty-five years later Congress authorized a survey of the Mississippi River with the aim of flood

protection in view. During the twenty-year period, beginning with 1879, Congress appropriated funds to construct levees along the Mississippi River. This federal work was done in cooperation with the parish levee boards, which were organized under state law.

Congress established the California Debris Commission in 1893. This was the first time the federal government showed interest in flood control outside the Mississippi Valley. The commission consisted of officers of the Corps of Engineers. It was to prepare plans for the control of mining refuse, which was clogging the channels of the Sacramento and San Joaquin Rivers in California. Twenty years later this work led to the development and installation of flood control plans for these rivers.

In 1908 Congress established the Board of Engineers for Rivers and Harbors. The purpose of this board was to improve navigation, but it soon became interested in related flood problems. Later Congress showed interest in controlling runoff and erosion. This interest was stated in the Weeks Forest Purchase Act in 1911. This act authorized the Secretary of Agriculture to take certain measures toward "regulating the flow of navigable streams."

The first Flood Control Act was passed in 1917, authorizing work on the Mississippi and Sacramento Rivers. It also stated that federal laws relating to rivers and harbors should also apply to flood control. This act was the first action of Congress indicating need for a broader consideration of river basin problems.

The Rivers and Harbors Act of 1920 required that both local and general benefits be determined. Local cooperation was suggested because of the local benefit.

Large-scale federal flood control activity began in 1928 in the lower Mississippi Valley. The Flood Control Act of 1936 provided for federal participation in flood control on a nationwide basis. In 1954 Congress recognized the importance of upstream watershed protection as a part of our water program.

We realize that a close relationship exists between land and water. But we have not combined our planning for their development, conservation, and use. At present we are using two planning methods. One is for treating individual farm and ranch units. The other is the multiple-purpose development by river basins. The farm plan does not cover anything off the farm. The river basin plan does not consider the effect in changed land use on runoff and silt production.

There is an important missing link between these two planning ideas.

A great deal is known about the relationship of land and water. We know that the proper use of watershed lands improves conditions by reducing runoff and sediment production. At the same time, it improves ground water supply. By the same token, conservation work on individual farms and ranches benefits those properties. But these works are usually installed with little regard to what happens elsewhere.

The missing link can be closed. It can be closed with a watershed protection program. In this program, work on one farm is related to that on the next. With enough attention, the needs of everyone can be met. This includes the farmer, his community, and the people living downstream.

THE WATERSHED PLAN

Sound plans are necessary for successful action. The first step in a watershed protection program is the preparation of a plan. This plan should show the kinds, quantities, costs, and locations of all needed soil and water measures.

WATERSHED PROTECTION MEASURES

Measures aiding watershed protection can best be classified by purpose. In terms of purpose there are, first, the land use and treatment measures. These are effective in increasing the infiltration and waterholding capacity of soil. They also reduce soil erosion. They include such measures as contouring, terracing, stripcropping, grassed waterways, rotations, pasture and woodland improvement. This class also includes watershed stabilization measures. Gully control is an example of this type of measure.

This group of measures benefit the farm: that is, they produce on-site benefits. The benefits occur on the fields and farms where the measures are installed. They also reduce danger downstream, but their main benefit is to the farm.

The second class of measures controls waterflow: that is, the management of water after it leaves the fields. They are flood control measures and their main benefit occurs off-site or downstream. Benefits from these measures do not occur on the farm or at the place where they are installed. They are public in nature and are known as off-site benefits.

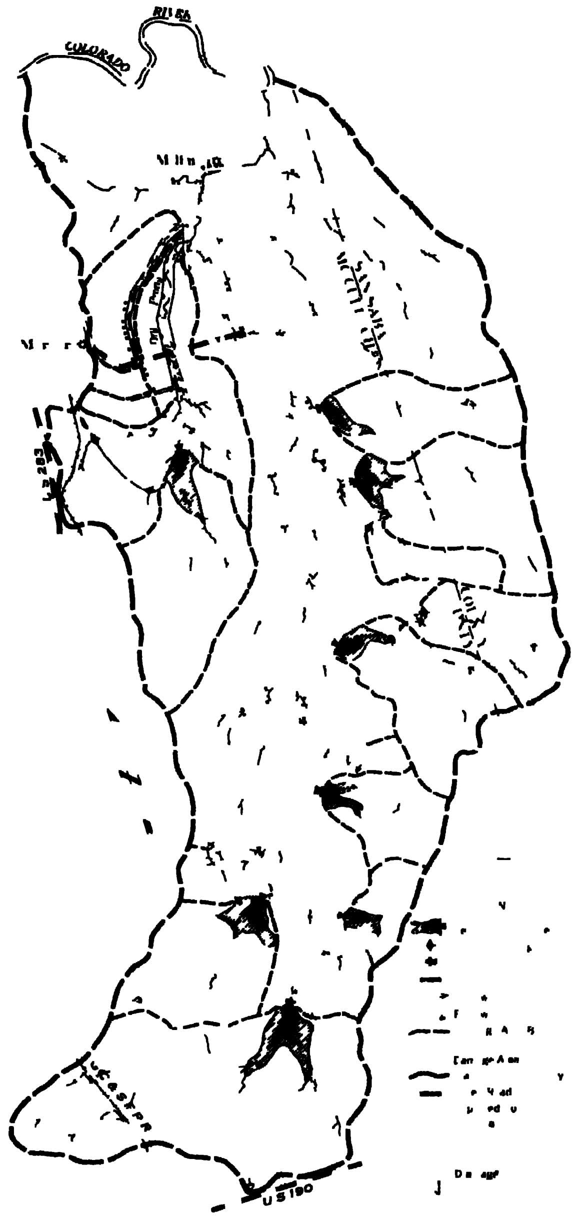


Figure 24-1. Floodwater-retarding structures and other water-management measures planned for the Deep Creek watershed, a tributary of the Colorado River of Texas (Soil Conservation Service Photo)

FUNDAMENTAL NATURAL PROCESSES

Knowledge of natural processes governing the behavior of soil, plants, and water is necessary for successful watershed management. We need to know how plants, soil, and water affect each other. We need to know what happens when we upset the relationships existing between them. How does cultivating a field affect it? What happens when we return cultivated land to trees or grass? These are only some of the things we need to know. There are lots of others.

We need to know how these things operate. If we do not, we may find we are doing more harm than good, as when we use terraces to stop raindrop splash, for instance. We need to know how the program we install affects the amount of water that gets off the farm. We need to know many other things too.

PURPOSE OF WATERSHED MANAGEMENT

The purpose of watershed management is to treat land and water problems together. They are interrelated: that is, one is dependent on the other. Likewise, one is affected by the other. What affects one affects the other. We need to know how what we do to one affects the other.

A watershed is a natural unit. It shows the interrelations of soil, geology (how soil was formed), water, and plants. It does this by producing a common product: runoff or stream flow. It shows how changes in either one or all of these affect stream flow.

Stream flow is an accepted way of judging watershed conditions. It also shows the effectiveness of watershed management. Changes in watershed management affect streamflow. As management improves, stream flow goes down. If management is less effective, stream flow goes up.

The soundness of planning and developing river basin units is now generally accepted. This is a sound approach because water flow is a product of the land.

LAND USE AND STREAM FLOW

The amount and rate of stream flow expresses the natural and agricultural characteristics and conditions of the watershed. Watersheds protected by plant cover have lower runoff rates than similar areas in cultivation. This is because more water is absorbed by pro-

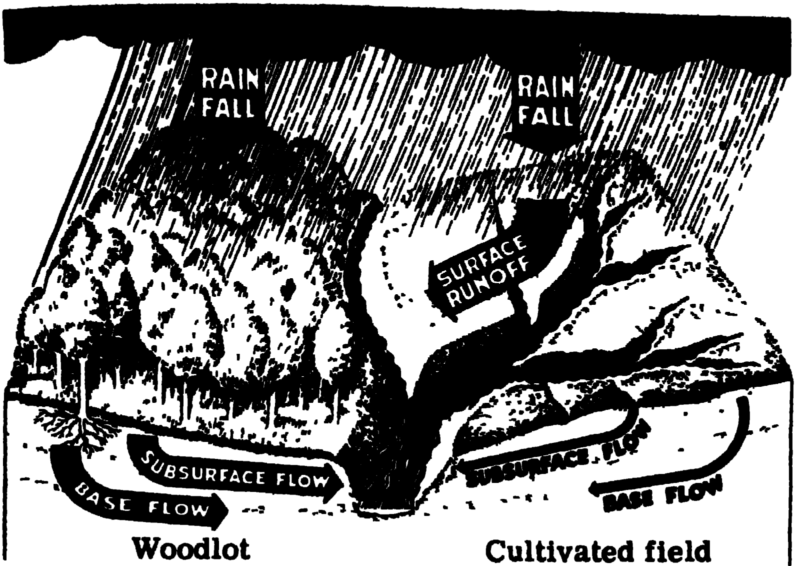


Figure 24-2. Land management determines how excess rainwater is removed from a watershed. Excess water may appear in the form of either surface runoff, subsurface flow, or base flow (from underground reservoirs which are the source of water for stream flow during rainless periods). Width of arrows shows the relative amounts of each kind (Forest Service Photo)

tected soil than by unprotected. There is less to fill the streams. Streams do not get so high and as a result, they cause less damage. It takes runoff water from wooded watersheds longer to get to the channels. And since it is clear when it gets there, it creates no silt problems and less flood damage. Runoff water from cultivated fields does just the opposite.

Characteristics of the soil determine its infiltration, percolation, and storage capacity. When infiltration and percolation rates and soil storage capacity are high, surface runoff from a given storm will be low. This is because most of the water is absorbed by the soil. With low infiltration rates and little storage, surface runoff will be high. Little of the water is absorbed by the soil.

WHITE HOLLOW WATERSHED

The White Hollow Watershed in eastern Tennessee has shown how good watershed management can eliminate danger from flood.

This area had been in cultivation. But as the plant cover improved, surface runoff declined and erosion was almost eliminated.

The White Hollow Watershed is 1,717 acres in area. It was properly managed for fifteen years. At the beginning of the study bare areas were seeded to grass. Grazing and fires were controlled the full time and trees and grass were allowed to grow.

The increased plant growth reduced runoff as much as 92 per cent during hard rains. The time required for runoff water to get to the stream channel was increased 500 per cent. The greatest change occurred in the watershed immediately after cultivation stopped. This was the time plant cover was established in the cultivated and overgrazed areas. The change was due largely to the increase in plant cover that followed after grazing and cultivation had been stopped.

The plant cover improved to such an extent that erosion was practically eliminated. White Creek now maintains a flow of clear water suitable for rearing trout.

RETENTION STORAGE AND STREAM FLOW

The effects of the treatment of vegetation on storage show up in the amount of stream flow. The proper management of plant cover increases infiltration, the amount of water stored, the depth to which water can be stored, and the water-holding capacity of the soil. It increases infiltration by keeping the soil loose and open at the surface. It increases water-holding capacity by increasing soil depth. It also increases the amount of water a given depth of soil will hold.

Watershed treatment also affects the available storage space at any given time. On bare soil available storage space is created by evaporation losses. The available storage space of bare soil often cannot be utilized. This is because the soil crusts. Little rainwater gets into the soil to be stored. On the other hand, evaporation is reduced where vegetation is present. But the total loss by transpiration plus evaporation is commonly greater than the loss by evaporation alone from a bare area. Thus, the possibility of retention storage is greater under vegetation. It is also created more rapidly than in bare areas.

NEED FOR WATER INCREASING

Today this nation is water conscious as it has never been before. More and more our water supply is being brought to our attention.

Water is the limiting factor in the development of cities, industry, and agriculture. Water is the key to sound resource management as well as to our future progress. The amount of water we have depends on the way we handle, conserve, utilize, and control it.

And yet this water we need is the same that comes roaring down our creeks and rivers, spreading hardship and destruction as it goes. There is only a slight difference between the pure, clear water flowing from our springs and wells and the yellow torrent flowing over our crops. The main difference is that the clear water stayed for a time where it fell—the other didn't.

The way to get enough good water and at the same time reduce our floods is to get rainwater and melting snow into the ground. The ground is the greatest and most wonderful reservoir of all. There is more natural water storage capacity in the earth than in all the man-made structures and reservoirs we can ever build on top of it.

Every drop of water retained in the area on which it falls is one drop subtracted from possible flood and one added to our useful water supply.

WATERSHED ELEMENTS

A watershed is made up of a number of individual communities. Each community has physical, economic, and social ingredients. A watershed is the land from which water flows into a stream, lake, or other point of drainage. But the geography is only one element of any watershed.

Other important watershed elements include timber or grass growing on the watershed and land in cultivation. They include land use: how the land is used for farming, grazing, lumbering, recreation, and wildlife. They include the condition of the watershed's land as to erosion and soil exhaustion versus soil fertility and productiveness. And the watershed includes, most importantly, people—people with their community interests.

All of these factors have to be taken into account. They have to be kept in their proper relationships for successful watershed planning and treatment. Plans on one farm must be related to those on other farms. In turn, the effect of watershed treatment on both rural and city property and facilities must be considered. This calls for working out systematic use of water from the top of each watershed to the bottom.

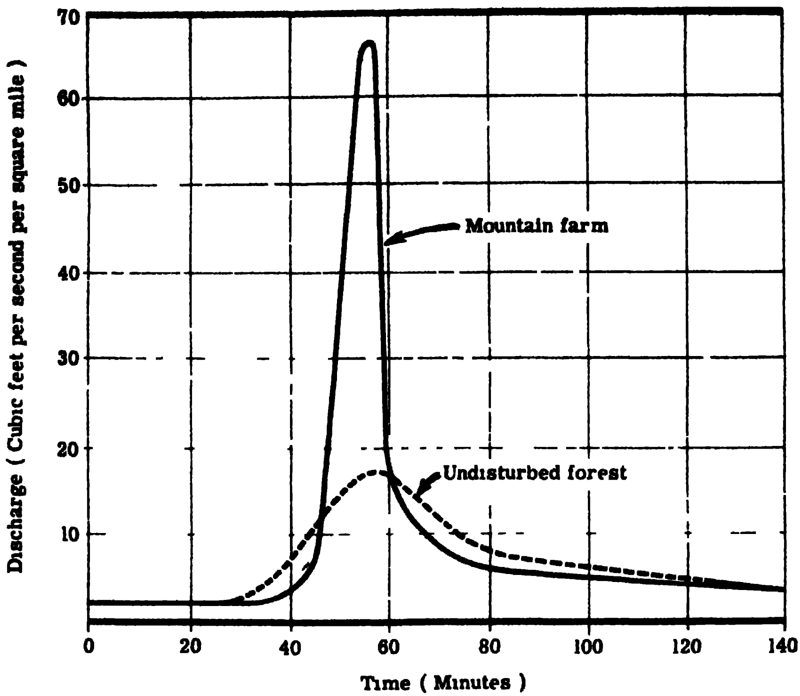


Figure 24-3. Comparative effects of crop and woodland farming on stream flow. Stream flow from cultivated areas is caused mainly by surface runoff. It occurs as flash floods. Stream flow from woodland comes from underground flow and is more uniform. (Forest Service Photo)

CONSERVATION

Conservation of natural resources does not mean hoarding. It means use in such a way that the greatest immediate production or benefits will be derived without exhausting the basic resources themselves. A sound conservation program results in increased production and improvement of soils both at the same time.

WATERSHED CONSERVATION IS ALL INCLUSIVE

If we accept these definitions of "watershed" and "conservation," then true "watershed conservation" becomes a rather all-inclusive undertaking. It means conservation, management, and use of all soil

Figure 24-4. Watershed management advances from individual farms to minor watersheds. A minor watershed meeting in Lancaster County, Nebraska. (Soil Conservation Service Photo)

Figure 24-5. A number of minor watersheds are combined to make larger watershed units. (Soil Conservation Service Photo)

and water. It also includes all things that depend on them. And it includes proper construction and maintenance of roads, highways, railroads, culverts, bridges, dams, and levees.

INTERDEPENDENCE OF WATERSHED RESOURCES

The way in which any one of these resources or developments is used or managed usually affects several of the others. For example, poor construction or maintenance of a road or highway may start gullying. The gullying may damage the crops and land of nearby farms. It fills streams with mud, which suffocates fish and contributes to floods downstream. Poor farming may lead to erosion that affects the entire economic life of a community and heightens flood crests. Improper cutting or burning of a forest may reduce or destroy the wildlife that resided there. It may lead to siltation and floods on the stream below.

A watershed conservation program must take into account each patch of land and the plants and animals that live on it. It must consider each rivulet, pond, or stream, each man-made structure, and every activity of the entire area.

THE WATERSHED IS A PHYSICAL UNIT

The laws of nature govern the conservation and development of our land and water resources. These laws are not limited by the boundaries of a valley or watershed.

A watershed is a geographic area constituted by the overland drainage that contributes waters to the flow of a particular stream at a chosen point. It is a "water-collecting" and "water-handling" unit. It is a topographic unit usually surrounded by other units of the same nature.

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The Conservation Movement

THE soil conservation movement in America is still young. It is only about twenty years old. Yet phenomenal progress has been made in that short time. Basic conservation plans have been developed for about one fifth of the nation's farms. More than 2,500 soil conservation districts have been organized. They blanket 76 per cent of the country's agricultural land and include more than 80 per cent of all farms in the nation.

Equally important is the progress that has been made in the evolution of the meaning of soil conservation and of conservation objectives. The original objective was to overcome the erosion menace to American land. Gradually, during the last twenty years, the idea has been broadened. Now the objective is to use each acre of agricultural land for the purpose for which it is best suited. Soil conservation also advocates treating the land in accordance with its needs for protection and improvement.

A quick look at historical crop yields in the United States is pertinent to the subject. Statistical records go back about eighty-five years. For the first seventy years of that period, average per-acre crop yields remained practically unchanged. Since 1940, there has been a sharp swing upward. Average per-acre yields have gone up about 40 per cent.

There were many scientific improvements in farming during that first seventy years. Obviously, other factors were operating to offset these improvements. Unquestionably, a major offsetting factor

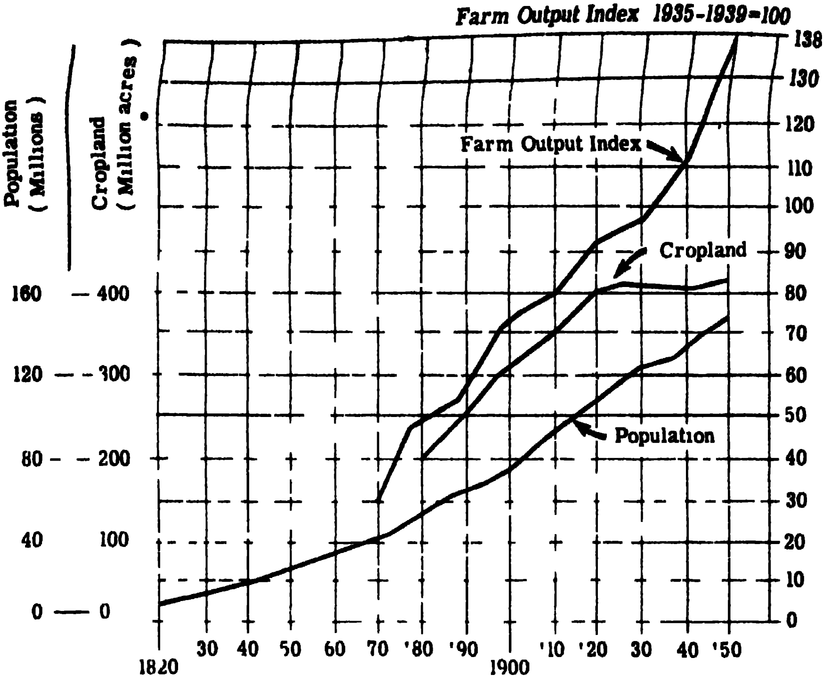


Figure 25-1 Trends in population, cropland, and farm output in the United States

was exhaustion of the natural fertility of our nation's soils The advantages from scientific improvements were offset by soil destruction

Most of the gain in the last fifteen years has resulted from recent improvements Mechanization has brought about the use of improved crop varieties like hybrid corn, the control of crop pests, improved land use, and better soil and water management The increased use of fertilizer and lime has played an important part. Increased soil productivity has been achieved on many farms But these achievements have not been enough to offset soil destruction on other farms

There are many farms throughout the country where erosion is still exacting a heavy toll On even more farms soil fertility is still on the downgrade On our most productive land, in the Midwest and Great Plains for example, exploitation systems have been followed They have been followed on many farms ever since the

land was broken. Much of the organic matter has been lost and the natural fertility of the soil has declined continuously. It is still going down.

Many of these soils, of course, are still productive. The point is they are not so productive as they once were. They are not so productive as they can be made We have available the scientific knowledge to manage many of these soils so as to build up and maintain their productivity. The problem is to get that knowledge into widespread use.

PRACTICES WORK BEST IN COMBINATIONS

The idea of soil conservation means applying the necessary practices on a farm. They are applied to increase production and to build up soil productivity—both at the same time. It means making soils yield abundantly year in and year out for an indefinite period. It means rebuilding strength in the land.

This is the main point of the whole idea You can conserve soil without improving it, but *you can't build soil up without conserving it*. Soil is like a living thing. Feed it right and treat it right,

Figure 25-2. The importance of soil conservation is being emphasized in our schools A group of Michigan school teachers studying conservation in the field (Soil Conservation Service Photo)

and it grows like any living thing—and produces more while it is growing.

There's more to conservation farming than controlling erosion. Conservation farming involves the use of combinations of good practices we now have or which research can discover for us. Soil can seldom be made to produce at its full capacity by using a single practice. The combinations are different in different areas—and on different kinds of soil. They may vary widely from farm to farm and from field to field.

The point is that good practices used in the right combination create interactions that give an added boost to production. One good practice may be beneficial. But the advantages often pyramid when several good ones are used in the right combinations. The reaction is much the same as the vigor in hybrid corn.

This principle can be described best with an illustration of corn growing in the South. Corn yields always had been low in the South. Until a few years back they never averaged more than twenty bushels per acre. For years farmers and scientists tried one new practice after another, but they couldn't get yields up much. They tried corn hybrids. They tried using more fertilizer. They tried increasing the stand. They tried first one thing and then another, but without much success.

In 1944 they changed their approach. Instead of testing first one practice, then another, and then still another—they tried several of them all at once. They tried combinations of practices and found some that hit the "jackpot." Corn yields jumped from twenty bushels to eighty bushels per acre.

Since this discovery, thousands of Southern farmers have adopted these new combinations of practices. Consequently, average corn yields have been doubled in some Southern States.

OUR PRODUCTION POSSIBILITIES

There is plenty of evidence that we haven't put into use all of the best combinations. Several studies aimed at estimating agriculture's maximum production capacity are underway. Preliminary results have been reported. They indicate that, with the best combinations of known practices put into use on all farms, production could be increased from 60 to 75 per cent. The studies indicate, for instance, that average corn and cotton yields in the United States

could be increased about 75 per cent. The potential for small grain and soybeans doesn't appear to be quite that high. For hay and pasture it appears that we could double production through grassland improvement.

If we expect to maintain the strong national economy required for world leadership, we must raise production. If we expect to feed—and feed well—the millions of new Americans being added to our population, we must increase production. If we expect to supply the growing demands of industry with products from the land, we must increase production. We must apply on our farms and ranches all the knowledge modern science has to offer. We must use all we now have plus all we can get through additional research.

There are two points to be made about estimates of our maximum possible capacity to produce. First, it is based on present knowledge. It does not take into account new scientific knowledge to come from future research. Second, the possibilities are for ideal conditions. They assume the application of the best-known combinations of practices for each farm for each crop. They also assume that every farmer would give top-level management to each acre of his land.

Obviously, we will never realize this ideal. Yet it is completely within the realm of practicability to greatly expand our capacity to produce. We can do this by making better use of scientific knowledge now available. This is demonstrated by the differences between what the average farmer is doing and what the best farmers are doing. The best farmers in all parts of the country are making their soils produce about double what the average farmers' are producing.

The job ahead is to narrow that gap. We may not be able to close it, but we need to do everything possible to narrow it. The need to speed up the use of improved scientific knowledge is the biggest challenge facing agriculture today. How well we succeed on that job will have a vital bearing on America's future capacity to produce food.

DETERMINING BENEFITS OF SOIL CONSERVATION

Costs and returns from soil conservation increase as more farmers adopt needed practices. A few farmers may apply more conserva-

tion measures to conserve the soil for future generations. Most, however, are interested in land management from the economic standpoint. They prefer to adopt conservation practices only to the point where net income can be maximized for a certain period of time. In many cases, these farmers want to know how these changes affect farm organization and income before they adopt them.

Costs and returns from conservation measures vary according to the amount applied. Controlled experiments and data from actual farms do not always give the desired economic information. Direct benefits from soil conservation practices are often considerably different from the indirect benefits. Economic returns from the short-time point of view are usually different from the benefits over a longer period of time. Conclusions regarding economic benefits are also influenced by the methods of management.

DIFFERENT DEGREES OF SOIL CONSERVATION POSSIBLE

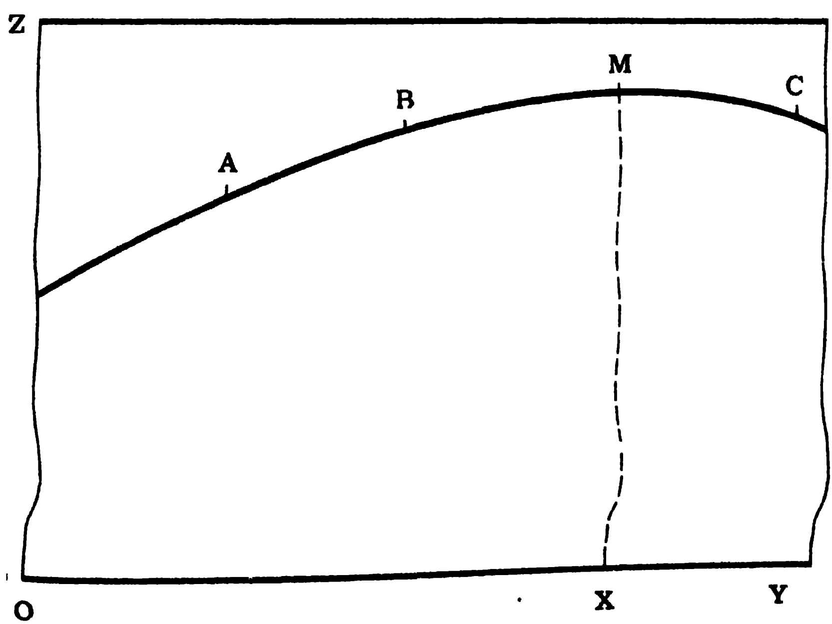
Possible returns from additional soil conservation practices are difficult to estimate. This is because conservation farming is a matter of degree. Different levels are possible on many farms because of the number of practices recommended. For example, some farmers follow a good rotation, but fail to adopt the necessary mechanical practices. Others apply adequate amounts of lime and fertilizer on the cropland, but continue to follow soil-exhausting practices. Different levels of conservation farming exist. They exist because of differences in the intensity of application. For example, some farmers apply larger amounts of lime and fertilizer than others. Considerable variation often exists in the amount of meadow crops raised in the rotation.

Since conservation farming is a matter of degree, economic considerations depend on the objectives to be accomplished. One objective might be to manage land resources so that erosion losses would be zero. Another objective might be to increase the productivity of the soil and maintain it at some previous level. In some cases, the goal might be to maintain soil productivity at the present level. For some soils the goal might be exhaustion to lower levels before stabilizing productivity. Additional conservation practices might also be applied as long as marginal costs did not exceed mar-

ginal income. Some of these goals would require larger areas for permanent pasture and woods than others. They might also require a high percentage of meadow crops on certain soil types.

The relationship between conservation farming and net farm income is illustrated in Figure 25-3. This chart shows how soil conservation practices applied to any farm may vary from small to extremely large amounts (represented by *O* and *Y*). As additional amounts of soil conservation are added, net income increases up to a certain point (marked *M*) and then declines. This situation occurs because all conservation practices may be applied to the point of diminishing returns. For example, fertilizer and lime can be applied in varying amounts until costs are greater than profits. Meadow crops may be increased to the point where farm income actually declines. This is especially true on farms where additional forage is used as residue or is fed to inefficient livestock. Contour strips could be made so narrow that the additional benefits won't pay for the additional costs and inconveniences. Tile lines could be spaced so closely that additional amounts would not pay for the extra costs.

Figure 25-3. Relationship between soil conservation and farm income.



In Figure 25-3 comparison between any two points with less than *X* units of conservation shows that additional units increase profits. Applications between *X* and *Y* would produce less income. This is because of diminishing returns from each additional unit. Comparisons between *A* and *B* would show certain differences in income from more soil conservation. Comparisons between *A* and *M* would show a greater difference in favor of larger amounts of conservation. Comparisons between *M* and *C* would show a slightly smaller income from the high rates of application. Under actual farm conditions, the amount of soil conservation that gives maximum profits depends on many factors.

DATA FROM CONTROLLED EXPERIMENTS

Controlled experiments are usually conducted at an experiment station. Here all factors are presumably constant, except the ones being studied. Station experiments are usually limited to study of individual practices. This is because of the complexity of measuring different degrees and intensity of soil conservation. Economic benefits from a complete soil conservation program are often difficult to determine from individual practice data. For example, returns from several practices do not always equal the sum of the practices taken individually. In some cases they may be more; in others they may be less. Most farmers are interested in the economics of applying several practices in combination. Few farmers adopt only one soil conservation practice.

Costs and returns of individual practices are often difficult to determine, even under controlled experiments. For example, it is difficult to estimate accurately how much sod waterways increase crop yields and income. They contribute to the ease of operating machinery on slopes subject to gully erosion. Returns from contour cropping are influenced by such factors as rotations, soil type, and past land management.

Controlled experiments are usually limited to a few soil types. Therefore, the data are often inadequate for many of the major soil associations. Some soils may be depleted in productivity and restored to previous levels without any permanent damage. In this case costs of soil depletion are actually the costs of restoring the productivity to some previous level. In addition to these temporary losses, other costs must be considered when permanent damage results from erosion. These costs vary according to soil type and

amount of erosion. The economics of soil conservation are affected also by the rate of soil erosion and fertility depletion. Some soils may be depleted in a shorter period of time than others.

Individual practice data are often inadequate. They don't show the effects on general farm organization. Fences may need changing to establish contour strip cropping or longer rotations. Field arrangement may be improved on some farms by fencing on the contour. On other farms, additional lanes and watering facilities may be needed. Contour cultivation may produce longer rows on some farms. But on others, pointed and crooked rows may interfere with the use of farm machinery. Data on rotations with more meadow crops do not show the additional costs for buildings and livestock to utilize more forage. Data on terracing seldom show the problems involved in maintaining terrace outlets. To protect these outlets on hog farms, the farmer usually has to fence the outlet. Or he may pasture the hogs in another field.

DATA FROM ACTUAL FARMS

Soil conservation data from actual farms usually cover a wider range of soil types and farming conditions than controlled experiments. Data from farms show the steps taken by farmers in adopting different conservation programs. Direct contacts with farmers provide information on the difficulties of establishing additional conservation. Farm records also show how certain farmers have adjusted their livestock program to utilize more forage crops.

Under actual farm conditions, data from different farms are often difficult to compare. There are wide variations in a number of such factors as the size of the farm, the type of soil, the kind of livestock, the methods of management, and the applications of lime and fertilizer. Some farmers may not apply large amounts of fertilizer until grain yields decline to low levels. Therefore, high applications of fertilizer do not always coincide with high yields. Data on previous farming practices are difficult to obtain because of changes in farm operations and inadequate records.

DIRECT VERSUS INDIRECT BENEFITS

Direct benefits from soil conservation practices are often considerably different from the indirect benefits. Returns from rotations with more meadow crops depend on whether the additional

forage is used as residue, sold, or fed. For most soils some meadow crops are needed in the rotation for maximum grain production. *Under certain conditions,* additional meadow crops not only increase forage production but also the total production. This relationship exists as long as reductions in acreage of grain are offset by sufficient increases in yields per acre. As long as total grain production increases when more meadows are raised, additional forage presents no problem. In this case, hay can be utilized as residue and the income will still be higher than if fewer acres of hay were raised. This is because a reduction in acreage of meadows would decrease production of both grain and forage.

The amount that grain yields must increase depends on (1) amount of meadow crops, (2) grain yields, and (3) proposed rotations. For example, grain yields per acre must increase one-third if total grain production is to remain the same under a rotation. Grain yields must increase where the rotation is corn, small grain, and two years of meadow compared with corn, small grain, and one year of meadow. If corn yields average forty-five bushels per acre for the three-year rotation, sixty bushels must be obtained under the four-year rotation. This is needed to offset the reduction in corn acreage. In this case, an increase of fifteen bushels per acre is needed to maintain total corn production. If corn yields seventy-five bushels for the three-year rotation, one hundred bushels per acre will be needed under the four-year rotation to maintain total corn production. In this case, an increase of twenty-five bushels per acre is needed. The same proportionate increase would be needed also for the small grain crops.

As more acreage of meadows is added to the rotation, a point is reached where total grain production declines. This occurs wherever yields per acre fail to increase fast enough to offset reductions in grain acreage. When total grain production declines as a result of adding more hay crops, net income often declines. It declines unless some income is obtained from forage crops. Economic returns from meadow crops depend on whether they are sold directly or fed to livestock. When fed, profits depend on the type and efficiency of the livestock kept, as well as on the price of livestock and its products.

Returns from rotations with more meadow crops will be low if large amounts of hay and pasture are fed to inefficient livestock. On the other hand, additional meadow crops may increase net farm

income on some farms when fed to high producing animals. Returns from feeding more forage to dairy cows is less in areas where the price of milk is low. It is more where the price is high. The higher the grain yield, the higher the return must be from hay and pasture to offset losses in income from fewer acres of grain. For example, forage fed to low-producing dairy cows might return as much per hour of labor as forty-five bushels of corn per acre. But considerably higher-producing dairy cows are needed to give the same return per hour from forage as seventy-five bushels of corn per acre.

SHORT-TIME VERSUS LONG-TIME BENEFITS

The economics of soil conservation depend on the period of time considered. In many cases returns from the short-time point of view are different from the benefits over a longer period of time. Individual farmers are usually interested in soil conservation from a shorter period of time than society. Therefore, the most economical application of practices for the farmer may not be the most desirable for society. Economic returns often vary during the transition period and the time the program is in full operation. Net income increases on many farms. It increases after sufficient time has elapsed to recover additional costs for soil conservation and changes in farm organization. During the transition period, net income may actually decline on some farms. For example, costs of liming cropland are not recovered on many farms until a meadow crop can be produced and marketed through livestock.

Higher grain yields from conservation rotations cannot be expected immediately. Only after better meadows are raised, larger residues returned, or higher rates of fertilizer used will benefits be apparent. Meanwhile, total grain production may decline. It may decline because of a reduction in the acreage of grain and because of the necessary adjustments made in farm organization. Several years may be required before the economic gains from terracing equal the cost of construction. Fencing woods against livestock and planting trees have little effect on increasing immediate farm income. Concrete structures increase cash outlays the year they are made. But expenditures for housing additional livestock cannot be recovered as quickly when new buildings are constructed as they can when present ones need only minor repairs.

RETURNS DEPEND ON UNITS OF MEASUREMENT

Economic benefits of soil conservation depend on how they are measured. Benefits depend on whether measurements are made in terms of (1) income per farm, or (2) income per man hour of labor. More meadow crops may increase net income on many farms. The amount depends on how the additional forage is utilized. On some farms this increase may be accomplished with the more efficient use of labor. In such cases the farmer increases his total income and the return per hour for his labor.

Sometimes, more meadow crops in the rotation may increase net income per farm. However, more labor is required to care for the additional livestock. Less grain and more hay increase the total income on these farms. Returns per man hour of labor is less, however. In other words, total income is increased because the farmer works harder, but he receives less per hour for his labor.

This situation occurs whenever forage crops produce less income per hour of labor than grain. Inefficient livestock and high grain yields are often responsible for the smaller hourly returns from meadow crops. Maximum returns per hour of labor may not be as important as maximum returns per farm. This is true in cases where there is plenty of labor but a small acreage of land.

RESULTS OF CONSERVATION FARMING IN ILLINOIS

A study made of more than a hundred farms in northeastern Illinois indicates that conservation measures are effective in maintaining soils for future use and are an important factor in increasing farm income. Investments to improve the land pay off in larger crop yields and in hay and pasture of higher quality. The same total amount of grain can be produced on fewer acres. Thus more acres can be shifted to hay and pasture. The shift allows livestock-minded operators to have more roughage-consuming livestock. This in turn makes it possible to increase productivity of the soil.

MORE EXPENSIVE BUT BRINGS GREATER RETURNS

On high-conservation farms an average of 48 cents more an acre a year was spent for lime and fertilizer during 1945–47 than on

low-conservation farms. In addition, 21 per cent of the land on the high-conservation farms was in soil-protecting legumes. Only 16 per cent of it was in these crops on the low-conservation farms. Corn yielded five bushels more an acre on the high-conservation farm. There was no difference in oat and soybean yields, however. More livestock and the higher corn yield caused the yearly net income to average $7.39 an acre more on the high-conservation farms.

The farms scoring highest in conservation practices followed a complete plan. The plan included (1) testing and treating the soil, (2) using the land according to its capabilities, (3) using rotations with ample acreage of deep-rooted legumes, and (4) using proper water disposal practices. These farms also utilized forage crops through livestock.

Conservation plans do not necessarily increase earnings immediately. This is because considerable effort and money must usually be expended before positive results are achieved. But the long-time benefits of conservation are certain. Over a long-term period, conservation farms that spent more money for soil and related improvements have more land in legumes and grasses. They have higher crop yields, produce more and better-quality hay and pastures, feed more livestock, have higher livestock production and returns, and receive larger farm incomes.

In all comparisons the high-conservation farms had higher livestock efficiency. It is believed that this was due to better-quality feed supplies. Crop and livestock production in Wisconsin was larger on farms practicing soil conservation than on farms where conservation was practiced less. This was also true with net income. The greater production usually is due to a combination of changes in land use and in crop production practices. It is important to measure the effect of soil conservation programs for a farm as a whole. But, it is also important to analyze benefits and costs of some of the parts of the program. Such analysis is helpful in making soil conservation plans for farms. This is because in many instances one soil-conserving practice may be substituted in whole or in part for another.

ALERTNESS ESSENTIAL

It is the alert farmers who study their business. They apply sound soil, crop, and livestock management principles to their en-

tire enterprises. They maintain their operations on a high and sound paying basis.

A study of farm account records was made of 240 similar Central Illinois farms. It showed that the 72 highest-earning farms earned annually an average of $3,740 a farm more than the 72 lowest-earning farms. They averaged this over ten years.

Eight efficiency factors accounted for about three-fourths of this difference. These factors and their net effects on net farm earnings were: crop yields, accounting for 27.5 per cent of the difference; livestock production efficiency, 11.4 per cent; labor cost, 10.3 per cent; price received for products sold, 8.5 per cent; immediate profitableness of the crop system, 6.3 per cent; decreased cost of operating machinery, 6.0 per cent; savings on crops produced and fed to livestock on the farm, 3.0 per cent; and building and fencing cost, 2.2 per cent.

Important relationships were found among the eight efficiency factors having appreciable effects on net earnings. Thus, farms with high crop yields usually had large amounts of livestock and more efficient livestock production.

The rate of earnings was slightly larger on farms having a medium-sized business than on farms with smaller or larger businesses. The medium-size business farm required about 24 man months of labor. Farms on which many hogs were produced had higher rates of earnings than farms with few hogs. This was due largely to the fact that corn-hog ratios were favorable to hog production during the ten years

Well-balanced farming led to the highest net farm earnings. In well-balanced farming, each of the factors having an appreciable effect on earnings was above average. Three farms that were above average in all eight factors earned annually $3,760 a farm more than the average of all 240 farms included in the study. Twelve other farms below average in seven of the eight factors earned $1,485 a farm less than the average of all the farms. A farmer may do excellent work along one or two lines and still have low net farm earnings. This is because he neglects other factors. The lowest-earning farm among all 240 farms was near the top in crop yields.

L'ENVOI

Soil conservation has come to mean proper land use: protection of the land against all forms of soil exhaustion. This includes re-

building eroded soil, conserving moisture for crop use, providing proper agricultural drainage and irrigation, building up soil fertility, and increasing yields and farm income - all at the same time

Modern conservation farming involves increasing soil productivity It aims to improve the standard of farm living for today, tomorrow, and for posterity It combines the objective of national welfare with better living for the people who work the land It now means efficient, abundant production on a sustained basis

Significant progress has already been made through the conservation movement Yet this is no time to rest on our laurels The job is too great

Figure 25 1 The conservation movement is worldwide A group of foreign exchange students studying land judging and conservation
(Soil Conservation Service Photo)

The demands on agriculture today are greater than they ever have been. The need for greater production is immediate and will be continuing. It will grow progressively over the years. The population in the United States is growing at the rate of 2.8 million persons per year. Our average life span has reached 67 years. There will be more of us to feed, clothe, and shelter for a long time to come. At the present rate of population increase, the demand on agriculture by 1975 will be 25 per cent greater than now.

We cannot look to new land to meet the increasing demands of the future. Instead, we have to depend on increasing per-acre yields. We must begin today improving every acre of our grassland, tree-land, and cultivated land, for a prosperous future.

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